THE PHYSICAL ENVIRONMENT AND PATIENT SAFETY: AN INVESTIGATION OF PHYSICAL ENVIRONMENTAL FACTORS ASSOCIATED WITH PATIENT FALLS

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THE PHYSICAL ENVIRONMENT AND PATIENT SAFETY:

AN INVESTIGATION OF PHYSICAL ENVIRONMENTAL FACTORS

ASSOCIATED WITH PATIENT FALLS

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SUMMARY

Patient falls are the most commonly reported “adverse events” in hospitals, according to studies conducted in the U.S. and elsewhere. The rate of falls is not high (2.3 to 7 falls per 1,000 patient days), but about a third of falls result in injuries or even death, and these preventable events drive up the cost of healthcare and, clearly, are harmful outcomes for the patients involved. This study of a private hospital, Dublin Methodist Hospital, in Dublin, Ohio analyzes data about patient falls and the facility’s floor plans and design features and makes direct connections between hospital design and patient falls. This particular hospital, which was relatively recently constructed, offered particular advantages in investigating unit-layout-related environmental factors because of the very uniform configuration of its rooms, which greatly narrowed down the variables under study.

This thesis investigated data about patients who had suffered falls as well as patients with similar characteristics (e.g., age, gender, and diagnosis) who did not suffer falls. This case-control study design helps limit differences between patients. Then patient data was correlated to the location of the fall and environmental characteristics of the locations, analyzed in terms of their layout and floor plan. A key part of this analysis was the development of tools to measure the visibility of the patient’s head and body to nurses, the relative accessibility of the patient, the distance from the patient’s room to the medication area, and the location of the bathroom in patient rooms (many falls apparently occur during travel to and from these areas).

From the analysis of all this data there emerged a snapshot of the specific rooms in the hospital being analyzed where there was an elevated risk of a patient falling. While this finding is useful for the administrators of that particular facility, the study also developed a number of generally applicable conclusions. The most striking conclusion was that, for a number of reasons, patients whose heads were not visible from caregivers working from their seats in nurses’ stations and/or from corridors had a higher risk of falling, in part because staff were unable to intervene in situations where a fall appeared likely to occur. This was also the case with accessibility; patients less accessible within a unit had a higher risk of falling. The implications for hospital design are clear: design inpatient floors to maximize a visible access to patients (especially their heads) from seats in nurses’ stations and corridors.

CHAPTER 1

INTRODUCTION

1.1 The Extent of the Problem: Inpatient Falls

Falls are the most common adverse events reported in hospitals across the United States (U.S.), England, Wales, Australia, and elsewhere (Morgan et al. 1985, Gaebler 1993, Williams et al. 2007, Healey et al. 2008). The rate of falls ranges from 2.3 to 7 falls per 1,000 patient days (Lane 1999, Halfon et al. 2001, Hitcho et al. 2004). Up to 33% of reported hospital inpatient falls result in injury (Morgan et al. 1985), with 4 to 6% resulting in serious injuries (Morse et al. 1985, Ash et al. 1998, Hitcho et al. 2004) that may lead to impaired rehabilitation and co-morbidity (Bates et al. 1995) and even death (Hitcho et al. 2004, Oliver et al. 2004). Falls are also associated with increases in hospital stays and healthcare costs and higher rates of both discharges to long-term institutional care and litigation against hospitals (Oliver et al. 2004). As of October 1, 2008, the U.S. government social insurance program Medicare no longer reimburses for costs associated with patient injuries resulting from falls and trauma that occur during hospital stays (Centers for Medicare & Medicaid Services 2008). Thus, patient falls are not only harmful but also costly to both patients and hospitals.

1.2 Intrinsic and Extrinsic Fall Risk Factors

Research shows that hospitals can reduce the incidence and severity of falls by identifying risk factors and introducing appropriate interventions that reduce them (Brandis 1999, Barry et al. 2001, Haines et al. 2004, Fonda et al. 2006, Williams et al. 2007). Risk factors include both intrinsic and extrinsic factors, and a complex interaction of such factors can result in a fall (The Joint Commission 2005a). Intrinsic factors involve patient-related characteristics such as age and disease and include previous falls, reduced vision, unsteady gait, musculoskeletal system deficits, mental status deficits, acute illness, and chronic illnesses such as neurological diseases (Stolze et al. 2004, The Joint Commission 2005a). Extrinsic factors relate to the physical environment of hospitals, including medication (especially sedative/hypnotics), lack of support equipment near bathtubs and toilets, inappropriate design of furnishings, the condition of floors, poor illumination, inappropriate footwear, improper use of devices (e.g., bedrails), and inadequate assistive devices (e.g., lifting device, walkers, and wheelchairs) (The Joint Commission 2005a, Tzeng and Yin 2008). For example, root-cause analyses of data on falls for all patients admitted over a three-year period in geriatric acute care units in Australia identified factors such as ward equipment (e.g., beds) and furniture (e.g., chairs), lighting, and floor surfaces as key contributing factors (Fonda et al. 2006). In a report to the Joint Commission outlining the latest sentinel event tracking efforts from 1995 to 2004 (The Joint Commission 2005b), the physical environment was also cited as one of the root causes of 144 fatal falls in 24-hour care settings. Even though the critical role of extrinsic physical environments on falls has been well-recognized, they have not been as studied in hospital inpatient settings thoroughly as in other settings such as long-term care facilities and elderly communities. While most hospital fall prevention strategies are comprised of interventions that focus on intrinsic fall risk factors, relatively few hospitals are engaged in assessing and modifying environmental risk factors of their hospital settings. Hospitals will benefit by addressing the complex interaction of intrinsic (patient-related) and extrinsic (environment-related) factors and incorporating environmental-related interventions into their multifaceted fall prevention intervention programs.

CHAPTER 2

THE REVIEW: AIMS AND THE PROCESS

2.1 Introduction

Chapter 2 reports aims and processes of the literature review exploring interventions implemented in all relevant domains of hospitals (i.e., the physical environment, the care process and culture, and technology) and their efficacy on falls and fall-related injuries and their underlying mechanisms.

2.2 Aims

The purpose of this review is threefold: (1) to evaluate the effectiveness of interventions implemented throughout all relevant hospital domains (i.e., the physical environment, the care process, and technology) on primary outcomes of interest (i.e., a reduction or no reduction in inpatient falls and fall-related injuries) and, then, to understand the role of the physical environment in fall prevention while understanding the collective effort of multi-systems in hospitals in preventing falls; (2) to determine the characteristics of interventions that can later facilitate the identification of the underlying mechanisms of interventions attributable to the primary outcomes in hospital settings; (3) to develop a hypothesis-generating multi-systemic model that establishes a practical framework within which hospital executives and nursing administrators can operate to develop a balanced fall prevention strategy that acts upon the physical environment, the care process and the culture, and technology.

2.3 Design

For the current review, we followed the guidelines of an internationally recognized organization (Centre for Reviews and Dissemination 2009). The guidelines outline the methods and steps necessary to conduct a systematic review in health care research and aims to avoid the risk of introducing bias. Due to the heterogeneity of interventions and populations, we conducted a quantitative systematic review without a meta-analysis and used a narrative summary technique to report findings.

2.4 Search Methods

We searched *Medline, CINAHL, PsycINFO,* and the *Web of Science* for references in peer-reviewed journals published between January 1990 and June 2009 that pertained to interventions targeting adult hospital inpatient populations with the aim of reducing falls and fall-related injuries. The search applied combinations of the search terms "falls," "injury," "intervention," "prevention," "hospital design," "physical environment," and "ergonomics" (Table 1). In addition, we searched for secondary references from acquired papers, review articles, and authoritative texts. One primary reviewer conducted the study selection, data extraction, and quality assessment under the supervision of another reviewer. Issues arising from the processes were resolved through discussion between the reviewers.

In a two-phase search strategy, we initially searched for fall prevention interventions with the primary outcomes—a reduction or no reduction in falls and fall-related injuries—through changes in all relevant domains in hospital settings and then added 25 studies during this process; then once noting the dearth of research pertaining to environment-related interventions in hospital settings, we also sought studies that evaluated the effect of environment-related interventions or factors on not only the primary outcomes but also associated intermediate outcomes such as a reduction in postural sway to enhance understanding of the underlying mechanisms of environmental factors that may produce the primary outcomes and added nine studies during this process.

The two-phase search strategy involved two different inclusion criteria. In the first phase, it included studies that (1) tested an intervention aimed at reducing falls and fall-related injuries in adult hospital inpatient populations and (2) reported the primary outcomes—a reduction or no reduction in falls and fall-related injuries. In the second phase, it included studies that (1) tested an environment-related intervention or factor whose purpose was to reduce falls and fall-related injuries in three adult populations (i.e., hospital inpatients, long-term care inpatients, and the elderly) and (2) reported either the primary outcomes or any associated intermediate outcomes. Included throughout the phases were the following study designs: randomized controlled, quasi-randomized controlled, controlled before-and-after, historically controlled, and cohort studies. Excluded throughout the phases were studies that neither reported the original research nor provided sufficient details about the research design or the components of the interventions, studies with duplicate hits, and studies published in languages other than English.

2.5 Search Outcome

The two-phase search strategy produced 6,723 studies (Table 1). After applying the inclusion and exclusion criteria to the titles and the abstracts from the first screening, we excluded 6,680 studies. We retrieved the full texts of the remaining 53 studies. The second screening of the full texts led to the removal of 19 additional studies. Thus, a total of 6,697 studies were excluded and 34 studies included after the first and second screening processes (Figure 1).

Table 2.1 Search Strategy

Database	Search Terms	Number of Hits
Medline	{(falls) AND (intervention or prevention) NOT (senior) NOT (residents) NOT (residential)} or {(injury) AND (falls) AND (intervention or prevention) NOT (senior) NOT (residents) NOT (residential)} or { (falls) AND (hospital, hospitals) AND (design)} or {(falls) AND (physical environment or ergonomics)}	2617
CINAHL	{(falls) AND (intervention or prevention) NOT (senior) NOT (residents) NOT (residential)} or {(injury) AND (falls) AND (intervention or prevention) NOT (senior) NOT (residents) NOT (residential)} or { (falls) AND (hospital, hospitals) AND (design)} or {(falls) AND (physical environment or ergonomics)}	743
PsychINFO	{(falls) AND (intervention or prevention) NOT (senior) NOT (residents) NOT (residential)} or {(injury) AND (falls) AND (intervention or prevention) NOT (senior) NOT (residents) NOT (residential)} or { (falls) AND (hospital, hospitals) AND (design)} or {(falls) AND (physical environment or ergonomics)}	528
Web of Science	{(falls) AND (intervention or prevention) NOT (senior) NOT (residents) NOT (residential)} or {(injury) AND (falls) AND (intervention or prevention) NOT (senior) NOT (residents) NOT (residential)} or { (falls) AND (hospital, hospitals) AND (design)} or {(falls) AND (physical environment or ergonomics)}	2,835
Total		6,723

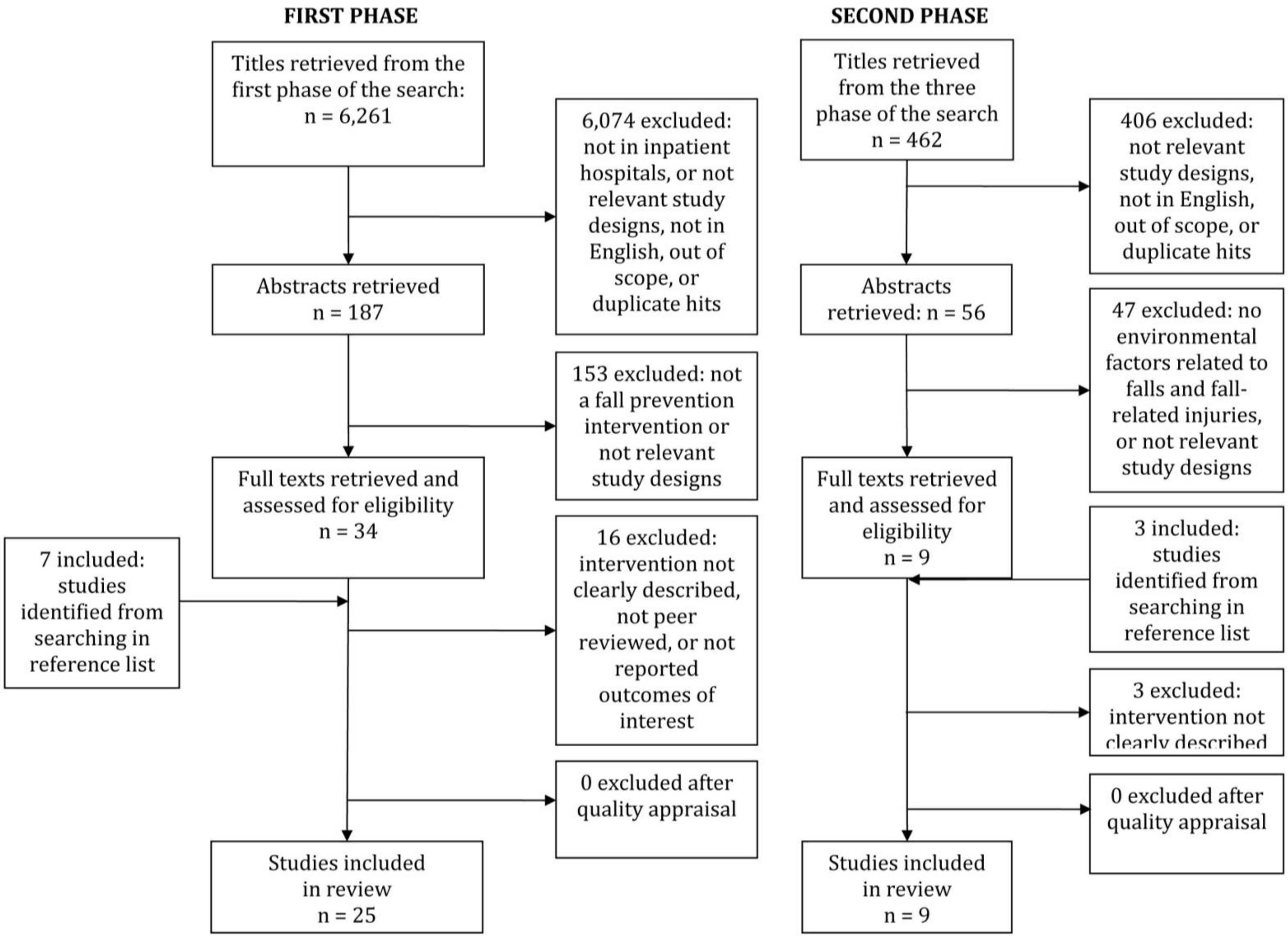


Figure 2.1 Flow Chart of the Study Selection Process

Table 2.2 Overview of Studies Included in the Review

Reference	CI	Settings	Study Design	Mean Age (yrs)/ Sample size	Components of Interventions	Findings	Number of Falls	Fall Rate	Falls with Serious Injuries (%)
Cumming et al. 2008	MH	24 elderly care wards in 12 hospitals in Sydney, Australia	Cluster randomized controlled	79/3,999 patients	EN, CP&C-, T-related 1) A structured fall risk assessment, 2) targeted interventions for high risk patients, and 3) minor environmental modifications	No sizable reductions in either falls or fall-related injuries in the intervention group	194 falls (IG)/190 falls (CG)	9.26 falls (IG)/9.20 falls (CG) per 1000 patient-days	NA
Krauss et al. 2008	MH	Four general medicine floors (two intervention and two control floors) in a 1,300-bed urban tertiary-care academic hospital, USA	Quasi-experimental with historical and contemporan-eous controlled	65.5±18.1 (IG), 65.5±17.5 (IG)/ 57 patients (IG), 78 patients (CG)	EN, CP&C-, T-related 1) A structured fall risk assessment, 2) targeted interventions for high risk patients, and 3) minor environmental modifications	Sizable reductions in falls (23% fewer falls) in the intervention group (a 9-month period):	57 falls (IG)/78 falls (CG)	5.09 falls (IG)/ 6.64 falls (CG) per 1000 patient-days	NA
Capan & Lynch 2007	MH	Medical/neurology units in a 357-bed acute care hospital, USA	Before and after	NA (patients of all ages)	CP&C-, T-related 1) A structured fall risk assessment, 2) targeted interventions for all patients at a high risk of falling (a total score of 30 or greater), 3) additional interventions, targeting individual-specific risk factors, and 4) re-administration of fall risk assessment every 12 hours	Sizable reductions in falls and fall-related injuries during the intervention: Total fall rate dropped from 0.45 per 100 patient-days to 0.32 per 100 patient-days. Severity of fall-related injuries also declined. Falls with minor and severe injuries decreased by 52% and 86%, respectively.	NA	4.5 (BI)/ 3.2 (AI) per 1000 patient-days	NA
Williams et al. 2007	MH	Three medical wards (comprising 72 beds) and a 17-bed geriatric evaluation unit in an acute tertiary teaching hospital, Australia	Before and after (6-month period)	79/ 1,357 patients	EN-, CP&C-, T-related 1) A structured fall risk assessment and 2) differentiated targeted interventions for each level of fall-risk patients	A significant reduction in falls from 0.95% to 0.8% (95% CI for the difference -0.14 to -0.16, $p < 0.001$) but no substantial changes in the severity of falls during the intervention	NA	0.95 (BI)/0.8 (AI) per 1000 patient-days	NA

Table 2.2 Continued

Reference	CI	Settings	Study Design	Mean Age (yrs)/ Sample size	Components of Interventions	Findings	Number of Falls	Fall Rate	Falls with Serious Injuries (%)
Von Renteln-Kruse & Krause 2007	MH	Geriatric wards in an academic teaching hospital, Germany	Historically controlled before and after	81.9± 7.9 (BI), 82.2 ± 7.7 (AI)/ 4,272 patients (BI), 2,981 patients (AI)	CP&C-, T-related 1) A structured fall risk assessment on admission (STRATIFY), reassessment after a fall and 2) targeted interventions for high-risk patients	A significant reduction in the rate of falls from 10.0 to 8.2 (IRR = 0.82, 95% CI = 0.73 – 0.92, p<.001) but no significant or sizable reductions in fall-related injuries from 26.9% to 27.6% during the intervention	893 falls (BI)/ 468 falls (AI)	10.0 (BI)/ 8.2 (AI) per 1000 patient-days	NA
Schwendi-mann et al. 2006		Three departments in a 300-bed hospital, Switzerland	Before and after	67.3 SD ± 19.3/34,972 patients	EN-, CP&C-, and T-related 1) fall risk assessment, 2) targeted interventions for patients at high risk of falling, and 3) additional interventions, generally applied to all patients	A slight decrease in the rate of falls to 7.87 falls per 1,000 patient days (p = 0.086) during the intervention	7.87 falls per 1,000 patient days (AI)	NA	NA
Fonda, Cook, Sandler, & Bailey 2006	MH	Acute care units for the elderly, Australia	Historically controlled before and after (2-year period)	80/ 1,905 patients (BI), 2,260 patients (AI-one year later), 2,056 patients (AI-two years later)	EN-, CP&C-, and T-related 1) A structured fall risk assessment, 2) targeted interventions for patients at high risk of falling, and 3) additional interventions, generally applied to all patients	Statistically significant reductions in both falls (19% fewer falls) (p = 0.001) and in serious fall-related injuries (77% fewer falls resulted in injury) (p =0.0004) in the intervention group (over a 2-year period)	NA	12.5 (BI)/ 10.1 (AI) per 1000 patient-days	0.73 (BI)/ 0.17 (AI)
Haines et al. 2004	MH	Three sub-acute wards in a Metropolitan Hospital specializing in rehabilitation and care of elderly patients Australia.	Randomized controlled	80 /626 patients	CP&C- and T-related 1) A structured fall risk assessment, weekly medical assessments, 2) targeted interventions for patients at high risk of falling, and 3) additional individual-specific interventions	A statistically significant reduction in both falls (30% fewer falls) (Peto log rank test p = 0.045) and a sizable reduction in fall-related injuries (28% fewer falls resulted in injuries) in the intervention group	105 falls for 310 patients (IG)/149 falls for 316 patients (CG)	NA	22 (IG)/ 21.5 (CG)

Table 2.2 Continued

Reference	CI	Settings	Study Design	Mean Age (yrs)/ Sample size	Components of Interventions	Findings	Number of Falls	Fall Rate	Falls with Serious Injuries (%)
Vassallo et al. 2004	MH	Three geriatric wards, United Kingdom	Quasi-experimental (open cluster random-ized controlled)	NA/825 patients	EN-, CP&C-, T-related 1) A structured fall risk assessment, 2) targeted interventions for patients at high risk of falling, and 3) additional individual-specific interventions	A sizable reduction in falls. The result was not definitive because of the differences in patients' average length of stay between the intervention and control groups.	72 falls for 5,855 OBDs (IG)/ 170 falls for 14,791 OBDs (CG)	NA	NA
Healey et al. 2004	MH	Elderly care wards in a district general hospital, England	Paired cluster randomized controlled (6-month-period)	80/ 1,861 patients (CG), 1,525 patients (IG)	EN-, CP&C-related 1) Interventions were only applied to patients at high risk and 2) patient-specific interventions	A statistically significant reduction in falls (RR 1.12, 95% CI = 0.55 – 0.90, *p* = 0.006) but no significant reductions in the incidence of fall-related injuries on intervention wards	240 falls (BI)/180 falls (AI) for 6 months	11.38 (AI) - 14.37 (BI)	2.69-3.07
Barry et al. 2001	MH	A rehabilitation unit, Ireland	Historically controlled before and after (2year period)	81/ 156 patients (BI), 172 patients (AI)	EN-, CP&C-, T-related 1) A structured fall risk assessment, additional risk assessment of remediable visual problems, mobility assistance and replacement of unsuitable footwear, provision of special footwear, and medication review and modification , 2) staff education, staff questionnaires regarding remediable environmental hazards, 3) environmental audits and modifications, and 4) hip protectors	A sizable reduction in falls: 21% fewer falls in Year I and 49.3% fewer in Year 2; a sizable reduction in the incidence of fracture: 20.5% of falls (pre-intervention) to 2.8% in Year 1 and no fractures in Year 2, a sizable reduction in soft tissue injuries in Year 2 but not in Year 1: a drop in Injuries from 38.5% (pre-intervention) to 36.1% (Year 1) and 15.4 % (Year 2)	71 falls (BI)/ 56 falls (AI) for the first year/36 falls (AI) for the second year	NA	14.7 (BI)/ 8.1 (AI) - first year/ 2.7 (AI) - second year

Table 2.2 Continued

Reference	CI	Settings	Study Design	Mean Age (yrs)/ Sample size	Components of Interventions	Findings	Number of Falls	Fall Rate	Falls with Serious Injuries (%)
Savage & Matheis-Kraft 2001	MH	Geriatric psychiatric wards, Canada	Historically controlled before and after (4- month period)	77.5	CP&C related 1) A structured fall risk assessment tool, an incident report form, and analysis and 2) patient specific interventions	A statistically significant reduction in falls after the intervention (*p* < 0.01)	11 falls (BI)/ 1 fall (AI) for 4 months	NA	NA
Brandis 1999	MH	A 500-bed acute general hospital, Australia	Before and after (2-year period)	NA (patients of all ages)/ 37,082 patients (BI), 42,389 patients (AI)	EN-, CP&C-, and T-related 1) Minor modifications of bathroom details, 2) interventions for patients at high risk, and 3) staff education	A sizable reduction in falls (17.3% fewer falls) but no significant reductions in fall-related injuries but a sizable reduction in the number of patients sustaining injuries from falls (70% of fallers (BI) to 55.5% (AI))	270 falls by 201 inpatients (BI)/258 falls by 190 inpatients (AI)	1.74-1.61	70 (BI)/ 55.49 (AI)
Mitchell & Jones 1996	MH	An acute/sub-acute medical ward, Australia	Historically controlled before and after (1-year period)	76	CP&C related 1) A specific fall assessment tool, 2) targeted interventions for high risk patients, and 3) staff and patient education and ongoing audits and feedback	A sizeable reduction in falls during the intervention	42 falls (BI)/ 21 falls (AI) for 6 months	4.4-7.8	NA
Donald et al. 2000	SH	An elderly care rehabilitation ward in a community hospital, UK	Randomized 2 X 2 controlled	NS/54 consecutive patients	EN-related Carpeted flooring/ CP&C-related additional exercise	Fewer falls on vinyl floors than on carpeted floors (relative risk 8.3, 95% confidence interval 0.95-73, *p* = 0.05)/ Fewer falls in the intervention group receiving additional exercise than in the control group receiving conventional physiotherapy (relative risk 0.21, 95% confidence interval 0.04-1.2, *p* = 0.12)	1 fall on vinyl flooring versus 10 falls on carpet flooring/4 falls (IG-additional exercise)/7 falls (CG)	NA	NA

Table 2.2 Continued

Reference	CI	Settings	Study Design	Mean Age (yrs)/ Sample size	Components of Interventions	Findings	Number of Falls	Fall Rate	Falls with Serious Injuries (%)
Hanger et al. 1999	SH	Five elderly care hospital wards from a hospital, New Zealand	Prospective before and after	NS/792 falls out of 1,968 admissions during a year	EN-related bedrail reduction	Statistically significant reduction in serious injuries in the intervention group (*p* = .008) No statistically significant differences between the fall rates before and after the intervention	NA	164.8 falls (BI)/ 191.7 falls (AI) per 10,000 bed days	33 falls (BI)/ 18 falls w/serious injuries
Haumschild et al. 2003	SH	A large urban rehabilitation center, USA	Retrospective before-and-after	79.6 (BI), 78.5 (AI)/200 patients (BI), 200 patients (AI)	CP&C-related medication reviews and modifications	Statistically significant reduction in the number of falls (*p* = 0.05)	30 falls (BI)/16 falls for one year each	NA	NA
Mayo et al. 1994	SH	A rehabilitation hospital, Canada	Stratified, randomized, balanced controlled	70.9 (12.6) (IG), 72.9 (11.8) (CG)/ 65 patients (IG), 69 (CG)	CP&C-related identification bracelets	No statistical differences between the intervention and the control groups (beneficial effect of an identification bracelet in reducing falls)	27 first falls (IG)/21 first falls (CG)	NA	NA
Bischoff et al. 2003	SH	Long-stay geriatric care units in a geriatric university hospital, Switzerland	Double-blind randomized	85.3 (range 63-99)/122 elderly females	CP&C-related vitamin D and calcium supplementation versus calcium-only supplementation	A statistically significant reduction in the number of falls (*p* < 0.01) and statistically significant improvement in musculoskeletal functions (*p* = 0.0094) in the intervention group (the Cal+D)	25 falls (14 persons) (IG)/55 falls (18 persons) (CG)	NA	NA
Haines et al. 2007	SH	A metropolitan subacute/aged rehabilitation hospital, Australia	Randomized controlled , subgroup analysis	NS/173 patients	CP&C-related additional exercise	Statistically significant reduction in the number of falls in the intervention group (*p* = 0.007).	8.2 falls/1,000 participant-days (IG)/16.0 falls/1,000 participant-days (CG)	NA	NA

Table 2.2 Continued

Reference	CI	Settings	Study Design	Mean Age (yrs)/ Sample size	Components of Interventions	Findings	Number of Falls	Fall Rate	Falls with Serious Injuries (%)
Haines et al. 2006	SH	A metropolitan subacute/aged rehabilitation hospital, Australia	Randomized controlled , subgroup analysis	NS/226 patients	CP&C-related patient education	Statistically significant reduction in the number of falls in the intervention group (p = 0.007).	8.2 falls/1,000 participant-days (IG)/16.0 falls/1,000 participant-days (CG)	NA	NA
Donoghue et al. 2005	SH	An acute care unit, Australia	Before-and-after	NS/NS	CP&C-related volunteer program	Statistically significant reduction (44%) in the fall rate per 1,000 bed days during the intervention (Fisher's exact Chi square, p < 0.000; OR 0.56, 95 % CI 0.45-0.68) No falls occurred when volunteers were present.	15.6 per 1,000 bed days (median 14.5, SD ±6.5, range 5.2-29.3) (BI)/ 8.8 per 1,000 bed days (median 9.8, SD ±3.0, range 1.1-13.2) (AI)	NA	NA
Giles et al. 2006	SH	Medical wards in two hospitals, Australia	Before-and-after	NS/NS	CP&C-related volunteer program	No falls when volunteers were present but no significant reduction in the fall rate during the intervention	70falls in 4,828 PBDs (BI)/82 falls in 5,300 OBDs (AI)	14.5 falls per 1,000 OBDs (BI)/15.5 falls per 1,000 OBDs (AI)	NA
Tideiksaar et al. 1993	SH	A geriatric evaluation unit at a teaching hospital, USA	Case-controlled	84 (range 67-97)/70 patients	T-related bed alarm	No statistical differences between the intervention and the control groups	1 fall (IG)/4 falls (CG)	NA	NA
Diduszyn et al. 2008	SH	One neurology and three telemetry floors at a 500-bed acute care university hospital, USA	Before-and-after	NS/NS	T-related bed alarm	Sizable reduction (18%) in the number of falls during the 4-month intervention period	78 falls (BI – the same period 1 year earlier)/64 falls (AI)	NA	NA

Table 2.2 Continued

Reference	CI	Settings	Study Design	Mean Age (yrs)/ Sample size	Components of Interventions	Findings	Number of Falls	Fall Rate	Falls with Serious Injuries (%)
Vassallo et al. 2000	EN	Three medical wards of a district general hospital, UK	Prospective cohort	64.51 (ward A), 66.48 (ward B), 64.02 (ward C)/1,609 patients (ward A 678, ward B 439, ward C 492)	EN-related nuclear layout wards (wards A and B) vs. a longitudinal layout ward (ward C)	The longitudinal layout ward (Ward C) had the most falls (31 vs 18/14: p = 0.01), fall positive days (29 vs 15/10; p = 0.002), and fallers (27 vs 13/12; p = 0.001: OR 2/54, CI-1.41-4.57). A ward layout is a significant independent risk factor for falls (p = 0.01) when controlling for age, sex, and diagnostic variation between the wards.	18 falls (ward A)/14 falls (ward B), 31 falls (ward C)	NA	NA
Hendrich et al. 2004	EN	An acute care hospital, USA	Before-and-after	NS/NS	EN-related acuity-adoptable rooms with decentralized nurses' stations	When the hospital changed its coronary intensive care units from two-bed rooms to acuity-adaptable single-bed rooms with decentralized nurse stations, patient transfers decreased by 90%, falls declined by 67%, and medication errors declined by 70%.	2 falls per 1,000 patient days (AI)	NA	NA
Redfern et al. 1997	EN	A laboratory	Experimental	23.8/8 young participants 76.0/8 older participants	EN-related floor compliance (softness)	Floor compliance (softness) increased the amount of sway in older participants (F = 3.83, $p < 0.001$). Floor compliance influences standing postural stability in older people, particularly in destabilizing visual environments.	NA	NA	NA
Dickinson et al. 2001	EN	A laboratory	Experimental	73.25 (range 60 to 88; SD ± 7.48)/25 older adults	EN-related floor compliance (softness)	The carpet increased postural sway among healthy, community-dwelling older adults ($p < 0.05$), compared to the firm surface with no carpet and pad applied.	NA	NA	NA
Dickinson et al. 2002	EN	A laboratory	Experimental	72.84 (SD ± 5.35)/45 older adults	EN-related floor compliance (softness)	No significant differences between the commercial-grade carpet and the firm surface with no carpet and pad applied	NA	NA	NA
Laing et al. 2006	EN	A laboratory	Experimental	24±3 (SD) /15 female participants	EN-related floor compliance (softness)	Impact forces decreased with increasing floor softness ($p < 0.001$).	NA	NA	NA

Table 2.2 Continued

Reference	CI	Settings	Study Design	Mean Age (yrs)/ Sample size	Components of Interventions	Findings	Number of Falls	Fall Rate	Falls with Serious Injuries (%)
Sran and Robinovitch 2008	EN	A laboratory	Experimental	25 ± 5 (SD)/11 young male participants	EN-related floor compliance (softness)	Impact forces decreased with increasing floor softness ($p < 0.001$).	NA	NA	NA
Healey 1994	EN	An elderly care unit, UK	Retrospective cohort	NS/NS	EN-related carpeted flooring vs. vinyl flooring	Out of a group of patients falling on carpet, only 17% sustained injuries. In the group of patients who fell on vinyl, 46% sustained injuries ($p < 0.01$).	NA	NA	NA
Simpson et al. 2004	EN	34 residential care homes, UK	Prospective cohort	NS/NS	EN-related carpeted flooring with wooden sub-flooring	Carpeted floors with wooden sub-flooring were associated with the lowest number of fractures per 100 falls. The risk of fracture resulting from a fall was significantly lower compared to all other floor types (odd ratio 1.78, 95% CI 1.33-3.35).	266 falls (wood-uncarpeted) /492 falls (concrete-uncarpeted) /2,812 (wood-carpeted)/3 071 (concrete-carpeted)		NA

CI = Characteristic of intervention
MH = Multifaceted interventions in a hospital setting
SH = Single interventions in a hospital setting
EN = Environmental research (non-interventional)
EN-related = Environment-related interventions
P&C-related = Care process & culture-related interventions
T-related = Technology-related interventions

BI = Before intervention
AI = After intervention
IG = Intervention group
CG = Control group
OBDs = Occupied bed days
NS = Not specified

CHAPTER 3

THE REVIEW: RESULTS

3.1 Multifaceted Fall Prevention Interventions

Fourteen studies that tested multifaceted fall prevention interventions in hospital settings were included in the review (Table 3.1). Twelve out of the 14 multifaceted fall interventions resulted in either a significant or sizable reduction in falls or fall-related injuries. Two studies report no sizable or significant reduction in falls: a quasi-experimental study in three geriatric wards in the United Kingdom (UK) (Vassallo et al. 2004) and a cluster randomized trial in 24 elderly care wards with relatively short lengths of stay in 12 hospitals in Australia (Cumming et al. 2008). However, because of the multifaceted nature of the interventions, it is difficult to isolate the effect of an individual intervention to determine which component of the interventions contributed to associated outcomes (a reduction or no reduction in falls). Thus, an in-depth analysis of the characteristics and the mechanisms of individual fall prevention interventions of the 14 multifaceted fall interventions was conducted. The analysis identified not only a wide range of currently available individual interventions but also three distinct characteristics of interventions: 1) the physical environment, 2) the care process and culture, and 3) technology-related interventions. Table 3 presents currently available individual interventions that are part of multifaceted interventions in hospitals, categorized into the three distinct characteristics of interventions.

Table 3.1 Individual Components of Multifaceted Interventions in Hospital

Interventions		References													
		Cumming et al. 2008	Krauss et al. 2008	Capan & Lynch 2007	Williams et al. 2007	Von Renteln-Kruse & Krause 2007	Schwendi-mann et al. 2006	Fonda et al. 2006	Haines et al. 2004	Vassallo et al. 2004	Healey et al. 2004	Barry et al. 2001	Savage & Matheis-kraft 2001	Brandis 1999	Mitchell & Jones 1996
Multifaceted Interventions (MH)		MH	MH	MH	MH	MH	MH	MH	MH	MH	MH	MH	MH	MH	MH
Environment															
Environmental Assessment/Audit										X	X‡	X‡		X	
Environmental Modification		X‡‡	X‡					X†		X ‡‡	X ‡	X †		X ‡‡	
Care Process & Culture															
Structured/Multifactorial Fall Risk Assessment Tool		X	X	X	X	X		X	X	X		X	X	X	X
Individual Fall Risk Assessment Tool	Mental status						X			X					
	Vision						X				X	X			
	Blood pressure										X				
	Medication review/modifi-cation	X	X				X			X	X	X			
	Urine test										X				
	Mobility test (e.g., get up and go tests)				X	X	X			X	X				
Fall Incident Assessment							X		X				X		X
Visible Signs and Identification Bracelets			X			X	X	X	X	X				X	X
Moving at-Risk Patients close to Nurses' Station			X								X		X		
Exercise		X							X						
Volunteer Program			X					X							
Patient/Family Education		X	X	X		X	X	X	X						X
Staff Education		X	X	X	X	X		X		X		X	X	X	X

Table 3.1 Continued

		Cumming et al. 2008	Krauss et al. 2008	Capan & Lynch 2007	Williams et al. 2007	Von Renteln-Kruse & Krause 2007	Schwendi-mann et al. 2006	Fonda et al. 2006	Haines et al. 2004	Vassallo et al. 2004	Healey et al. 2004	Barry et al. 2001	Savage & Matheis-kraft 2001	Brandis 1999	Mitchell & Jones 1996
Forced Care Routines	Prompted/ Regular toileting		X	X	X		X								
	Early feeding of dependent patients							X							
	Regular 2-hour monitoring		X		X										
	Continence aids				X										
	Intensified supervision of patients' transfer and toilet use					X									
Technology															
Hip Protector				X			X		X					X	
Foot Wear Safety Assessment/Modification		X				X	X			X	X	X			
Non-slip Footwear					X								X		
Bed Alarm		X	X	X				X							
Electronic Low Bed			X	X				X			X				
Nurse Call Button/Bell								X		X					
Provision of Walking Aids		X		X	X	X	X			X		X			
Provision of Toilet Aids (e.g., commode or urinal)			X		X					X					
Study Outcomes															
Significant Reduction of Falls					X	X		X	X		X				
Sizable Reduction of Falls			X	X			X					X	X	X	X
Significant Reduction of Fall-related Injuries												X			
Sizable Reduction of Fall-related Injuries				X				X	X					X	
Sizable Reduction of Fall-related Injuries				X				X	X					X	

3.2 The Impact of the Care Process and Culture and Technology on Inpatient Falls

3.2.1 Care Process- and Culture-Related Single Interventions

3.2.1.1 Medication Review and Modification

A retrospective before-and-after study that examined the medical records of 400 patients in one large urban rehabilitation hospital in the U.S. found that the pharmaceutical intervention reduced falls by 47% (30 in pre-intervention versus 16 in post-intervention, $p = 0.05$) (Haumschild et al. 2003). The study included the following interventions: reviewing all medications, listing medications associated with dizziness, falls, or fractures, educating nursing personnel on precautions for drug administration, and recommending medication frequency or dosage reduction resulting from collaboration among doctors.

3.2.1.2 Identification Bracelets

A one-year randomized trial involving 134 high-risk patients in a rehabilitation hospital in Canada found that the single intervention of identification bracelets was of no benefit in reducing falls among high-risk patients (Mayo et al. 1994). In the intervention group (with blue bracelets), 27 patients (41%) fell at least once whereas in the control group (with no bracelets) 21 patients (30%) fell at least once, yielding a hazard ratio of 1.3 (95% confidence interval: 0.8 to 2.4). This finding may suggest that simple awareness or a warning may not sufficiently reduce the number of falls. Thus, the decreased risk of falling necessitates other intervention strategies.

3.2.1.3 Vitamin D and Calcium Supplementation

Vitamin D and calcium supplementation over a 12-week period effectively reduced falls among long-stay geriatric patients (Bischoff et al. 2003). This double-blind randomized controlled trial involving 122 elderly women in Switzerland found that the vitamin D plus calcium supplementation significantly improved the musculoskeletal function of this group (p = 0.0094) and accounted for a 49% reduction in falls ($p < 0.01$). However, the calcium-only group did not show a significant decrease in the number of falls. Since this is the only available study that tested this intervention, further studies that ascertain the efficacy of this strategy on geriatric patient populations as well as other hospital patient populations are needed.

3.2.1.4 Exercise

An exercise program in addition to a hospital-wide multifaceted fall prevention program in a sub-acute hospital setting in Australia effectively reduced the number of falls (Haines et al. 2007). This randomized controlled trial involving 173 patients found that the intervention group suffered a significantly lower incidence of falls than their control group counterparts (control: 16.0 falls/1,000 participant-days; intervention: 8.2 falls/1,000 participant-days; log-rank test: p = 0.007). In contrast, a nine-month randomized 2 X 2 controlled trial of 54 consecutive patients in an elderly care rehabilitation ward in the UK found no statistically significant reduction in falls but observed a clinical tendency toward a reduction in falls in the experimental group (additional exercise; 4 falls) compared to the control group (only conventional physiotherapy; 7 falls) (relative risk 0.21, 95% confidence interval 0.04-1.2, p = 0.12) (Donald et al. 2000). The findings suggest that an exercise program may be effective only when implemented as part of a multifaceted intervention. However, both studies presented some limitations in the study design and analysis necessitating further study. The former did not adequately adjust the possible impact of a patient-sitter program introduced only to the experiment group in the analyses. The latter, as discussed earlier (carpeted flooring), presented a small sample size with limited sensitivity to the outcome measures.

3.2.1.5 Patient Education

A randomized controlled trial involving the subgroup (*n* = 226) of the larger randomized controlled trial (*n* = 626) (Haines et al. 2004) in a sub-acute hospital setting in Australia found that the intervention group (patient education program) in this subgroup analysis had a significantly lower incidence of falls than their control group counterparts (control: 16.0 falls/1,000 participant-days, intervention: 8.2 falls/1,000 participant-days, log-rank test: p =0.007) (Haines et al. 2006). However, it should be noted that the intervention group received the patient education program along with a hospital-wide multifaceted fall prevention program. That is, the patient education program may not be effective in isolation. In addition, the intervention should be applied to appropriate patient populations such as those with no severe communication or learning impairment.

3.2.1.6 Volunteer Companion Program

One 19-month before-and-after study in a geriatric acute care ward in Australia observed a statistically significant decrease (44%) in the fall rate per 1,000 bed days ($p < 0.000$; OR 0.56, 95 % CI 0.45-0.68) (Donoghue et al. 2005). According to findings of the first four months of the implementation period (August 1- December 17, 2002), the study showed that no falls occurred when volunteers were present. Another four-month before-and-after study in medical wards in South Australia found that volunteers played an important role in preventing falls and that no patient falls occurred when volunteers were present (Giles et al. 2006). The studies, however, emphasized the importance of appropriate volunteer training and on-going education in maintaining the efficacy of the intervention.

3.2.2 Technology-Related Interventions

3.2.2.1 Bed Alarm System

Despite observing a clinical tendency toward fall reduction, studies investigating the efficacy of a bed alarm system did not observe a statistically significant reduction in the number of falls (Tideiksaar et al. 1993, Diduszyn et al. 2008). A nine-month case-controlled study with 70 increased-risk patients at a geriatric evaluation unit at a teaching hospital in the U.S. found only a slight reduction in bed falls between the control (n = 4) and experimental group (n = 1) (Tideiksaar et al. 1993). A recent four-month before-and-after study on one neurology and three telemetry floors of a 500-bed acute care university hospital in the U.S. showed a reduction in the number of falls (78 in baseline versus 64 in implementation) when nurses carried an advanced alarm system with a portable beeper that they could hear clearly (Diduszyn et al. 2008). However, without controlling for other significant factors (e.g., patient census and characteristics) affecting the number of falls, the efficacy of this intervention is open to debate.

3.2.3 The Impact of the Physical Environment on Inpatient Falls

3.2.3.1 <u>Environment-Related Single Interventions</u>

3.2.3.1.1 Environmental Assessment and Modification

While identifying seven studies that implemented an environmental assessment and modification intervention as part of their multi-faced fall prevention intervention strategies (See Table 2), the review identified no studies in healthcare settings that tested the efficacy of environmental modification interventions as a single intervention.

3.2.3.1.2 Carpeted Flooring

The review identified only one environmental factor, *flooring*, tested as a single intervention in a hospital setting (Donald et al. 2000). A nine-month randomized 2 X 2 controlled trail of 54 consecutive patients at elderly care rehabilitation wards in the UK found that fewer falls occurred on vinyl floors (one) than on carpeted floors (ten) (p = 0.05). Although counter-intuitive, the study indicates that vinyl floors decrease the risk of falling. However, as the study was limited by a small sample size (n= 54) with limited sensitivity to the measures (only 15 falls), further research that detects a meaningful difference between groups is needed.

3.2.3.1.3 Bedrail Reduction

One bedrail reduction program with appropriate staff education effectively reduced the number of serious injuries in elderly care hospital wards in New Zealand (Hanger et al. 1999). While finding an insignificant increase in the number of falls, this one-year prospective before-and-after study involving a total of 1,968 patient admissions found a significant decline in the number of serious fall-related injuries after the bedrail reduction policy and education program was introduced (33 versus 18 serious injuries $p = .008$) (Hanger et al. 1999). Although bedrails have traditionally been recognized as a safety device that reduces patient falls, the study indicates that bedrails increase the severity of fall-related injuries. However, it should be noted that bedrail reduction coincided with staff training in alternatives for bedrails, such as nightlights, regular toileting regimens, and treatment for delirium when bedrails were removed. This suggests that bedrail reduction programs should be implemented along with appropriate alternative strategies for preventing falls, namely, patient consultation and staff education.

3.2.3.2 Environment-related Research: Non-interventional Studies

Once noting the dearth of research pertaining to environment-related interventions in hospital settings, we also sought studies that evaluated the effect of environment-related interventions or factors on not only the primary outcomes but also associated intermediate outcomes such as a reduction in postural sway to enhance understanding of the underlying mechanisms of environmental factors that may produce the primary outcomes and added nine studies during this process.

3.2.3.2.1 Unit and Patient Room Design

A four-month prospective observational study involving 1,609 patients at three acute medical wards in the UK investigated patient and ward characteristics (e.g., ward layouts) associated with falls (Vassallo et al. 2000). The three acute medical wards, distinctly different in their structural layouts, offered different ranges of visual access to a patient's bed. While a 40-bed longitudinal layout ward (A) had only 20% of beds visible from nursing stations, a 40-bed (B) and a 28-bed (C) nuclear layout ward had 85%. The study found that the former was associated with a significantly higher number of falls and fallers than the latter: 31 (A) versus 18 (B)/14 (C) falls ($p = 0.01$) and 27 (A) versus 13 (B)/12 (C) fallers ($p = 0.001$: OR 2/54, CI-1.41-4.57). Among the three, no significant differences had been found in ward turnover rates, mortality rates, and diagnostic groupings of patients. This study showed that their layout characteristics were significant independent risk factors for falls, even when controlling for sex, age, and mortality through logistic regression analysis. A before-and-after study utilizing data from two years prior and three years after a renovation at the Methodist Hospital and Clarian Health Partners in the U.S. investigated the impact of a unit layout on several process and patient outcomes such as transfers, falls, and medication errors (Hendrich et al. 2004). The study reported that when the hospital changed its coronary intensive care units from two-bed rooms to acuity-adaptable single-bed rooms with decentralized nurse stations, patient transfers decreased by 90%, falls by 67%, and medication errors by 70%. Both reductions in transfers and increases in patient visibility appear to be associated with a reduction in falls.

3.2.3.2.2 Flooring

Two laboratory experiments found that greater floor compliance (softness) increased postural sway in healthy older participants (Redfern et al. 1997, Dickinson et al. 2001). One suggested that floors with minimum softness, including uncarpeted (e.g., vinyl) or carpeted floors without padding, were associated with a lower risk of falling. The other found that, compared to the firm surface with no carpet or padding, a particular commercial-grade carpet did not increase postural sway (Dickinson et al. 2002). Ultimately, the randomized 2X2 controlled trial of 54 consecutive patients conducted by Donald et al. (2000), as discussed earlier (carpeted flooring), found that more falls occurred on carpeted floors (ten) than on *vinyl floors* (one) (p = 0.05).

Softer floors may reduce the severity of injuries (e.g., hip fractures) by applying lower forces to the hip during a fall (Laing et al. 2006, Sran and Robinovitch 2008). A retrospective study that analyzed a sample of 225 fall accident forms over four years, selected at random, in an elderly care unit in the UK found that patients who fell on carpeted floors were less likely to sustain injury than those who fell on vinyl flooring (Healey 1994). While 46% of patients who fell on vinyl floors sustained injuries, only 17% of patients who fell on carpeted floors sustained injuries. Another two-year prospective cohort study conducted at 34 residential care homes in the UK found that of all the floor types (i. e., uncarpeted with wooden sub-floors, carpeted with concrete sub-floors, and uncarpeted with concrete sub-floors), carpeted floors with wooden sub-floors were associated with the lowest number of fractures per fall (odds ratio 1.78, 95% CI 1.33-2.35) (Simpson et al. 2004). To achieve both a lower incidence of hip fractures and better balance, we must conduct further studies that determine the optimal degree of softness of a floor and a proper flooring type.

3.2.4 Multi-systemic Fall Prevention Model

The two multi-systemic fall prevention models emphasize the synergic effects of a multi-systemic approach that acts upon the three domains of hospitals (i.e., the physical environment;

the care process and the culture; and technology) in preventing falls and injuries (Figures 2 and 3) and facilitates the understanding of the detailed mechanisms of individual fall prevention interventions that lead to a reduction in falls and injuries (Figure 2). In this model (Figure 3), environmental-, care process- and culture-, and technology-related interventions or factors associated with falls and injuries are presented on the left and linked to their mechanisms and outcomes of interest (e.g., reducing falls and injuries) on the right. Asterisks represent the strength of evidence supporting each intervention: 1) One asterisk (*) denotes an intervention or a factor whose efficacy was NOT tested as a single factor in any healthcare setting; 2) two asterisks (**) represent an intervention or a factor whose efficacy was tested as a single factor in other healthcare settings but not specifically in a hospital setting; and 3) three asterisks (***) denote an intervention or factor whose efficacy was tested as a single factor in a hospital setting.

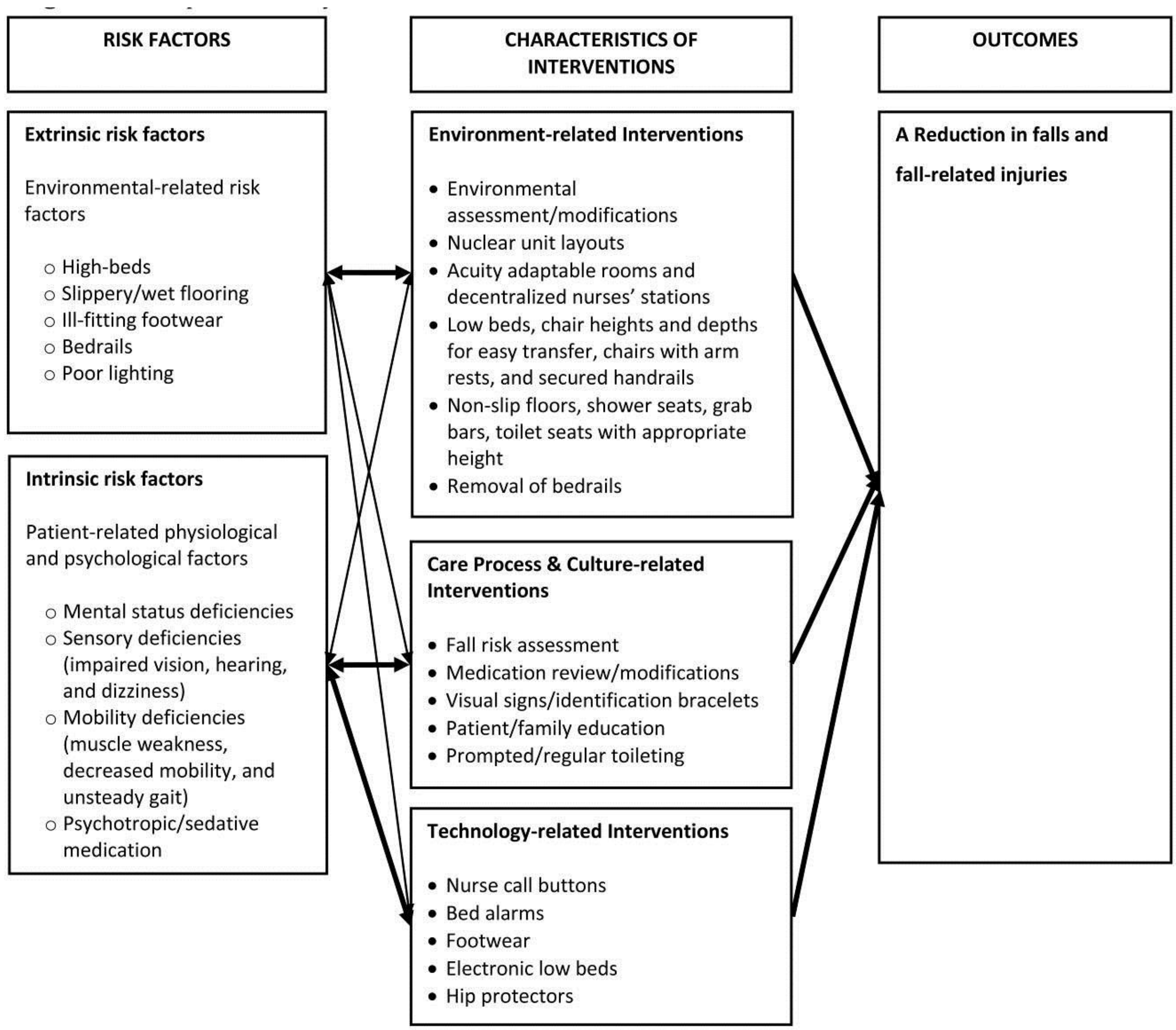


Figure 3.1 Conceptual Multi-Systemic Fall Prevention Model

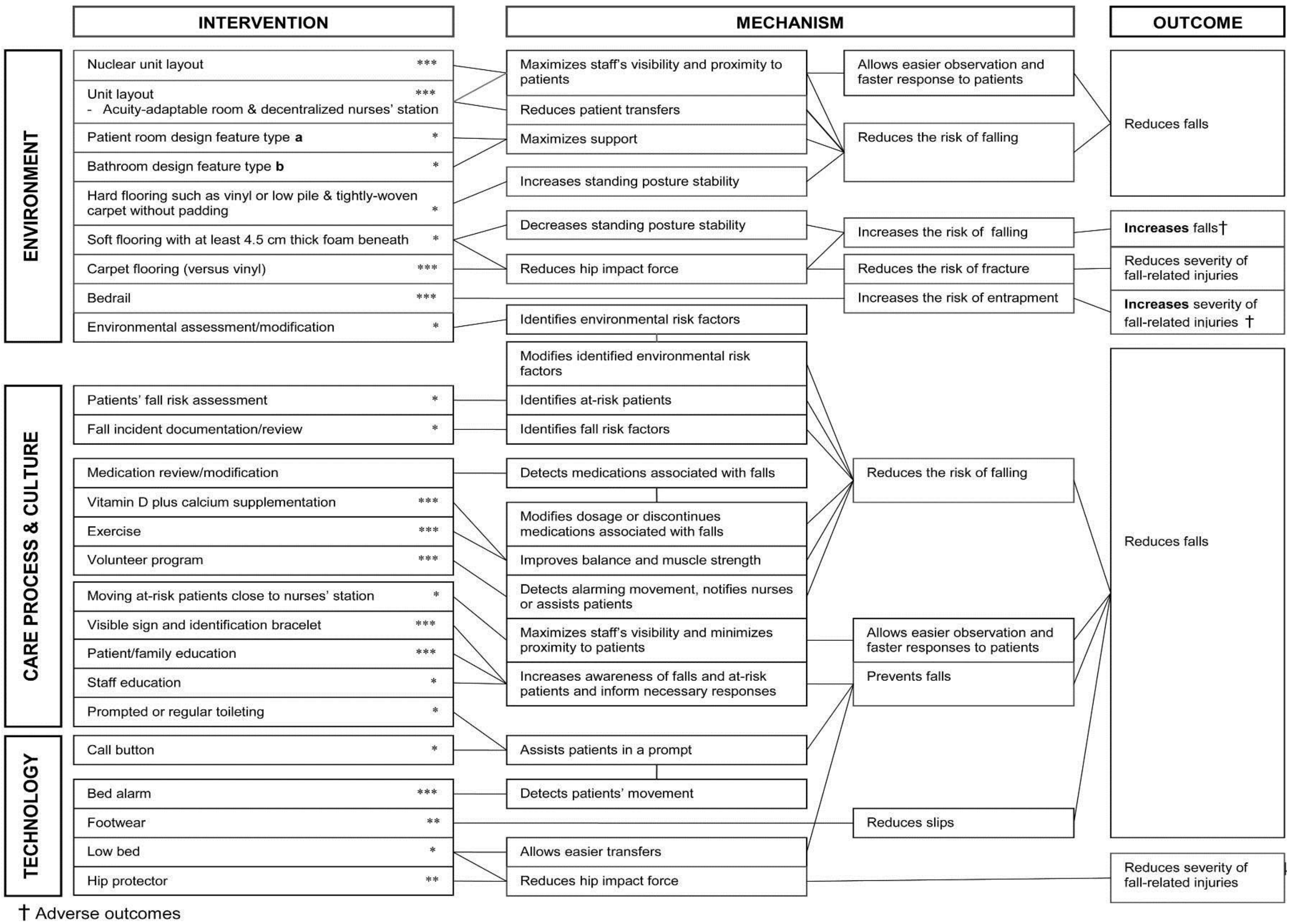


Figure 3.2 Multi-systemic Fall Prevention Model

a Firm mattresses; low beds; appropriate chair heights and depths for easy transfer; chairs with arm rests; and secured handrails throughout the movement of a patient

b Nonslip surfaces in floors/bathtubs; shower seats; grab bars next to the toilet/bathtub; toilet seats that allow easy transfer; door magnets that hold doors in the open position; and arm rests next to the toilet

* An intervention or a factor whose efficacy was NOT tested as a single factor in any healthcare setting

** An intervention or a factor whose efficacy was tested as a single factor in other healthcare settings but NOT specifically in a hospital setting

*** An intervention or factor whose efficacy was tested in a hospital setting

CHAPTER 4

THE REVIEW: DISCUSSION AND CONCLUSIONS

4.1 Discussion

The results of the review indicate that hospitals often employ two broad strategies to fall prevention. The most frequently-used approach is to implement care process- and technology-related interventions targeting at-risk patients by evaluating a patient's risk of falling and modifying his/her individual fall risk factors. This includes two of the three systems identified above: care process and technology. The other approach is to provide a safe and supportive environment that allows better visual access and closer proximity to patients and includes few or no environmental hazards and more assistive devices for patients, family members, and staff. Such environmental features help mitigate falls, assist patients during activities, and also facilitate prompt staff monitoring and the detection of alarming patient movements before they lead to falls.

Despite clinically significant evidence that supports the importance of the physical environment in preventing falls, only a few hospitals have been identified in the literature as introducing environment-related interventions (e.g., environmental assessment and modification) as part of their multifaceted fall intervention strategies. Most implemented a considerable number of care process-related interventions that may demand time and effort from nurses to ensure their effectiveness, which could be undermined by low compliance.

While some care process and technology interventions can be demanding on staff, some environment-related interventions could actually facilitate staff jobs. Studies suggest that certain unit layouts (i.e., acuity-adaptable patient rooms with decentralized nurses' stations and nuclear layout units) increase staff visibility and proximity to patients, which would allow nurses to easily detect any risky patient movements and facilitate their response to a patient in a timely manner. In addition, supportive design features introduced by environmental assessment and modification interventions (e.g., secured handrails throughout patient movement paths and non-slip flooring) would reduce the risk of falls by assisting patients during various activities.

This review has several limitations. First, two independent reviewers were not involved in the processes of the study selection, quality appraisal, and data extraction. One primary reviewer was involved in these processes under the supervision of another reviewer in the study. Second, no studies were excluded after the appraisal process. Both limitations mentioned above may have increased the risk of bias in the review. In addition, due to the heterogeneity of interventions and outcome measures, a meta-analysis of pooled results could not be conducted. Thus, the findings were described narratively. Another limitation was that no papers in languages other than English were included, which may limit the generalisability of the findings. The search strategy was also limited to electronic databases, and so publication bias could not be excluded. Moreover, generalisability may also have been sacrificed because qualitative evidence was excluded from the review. As the model in this study includes only quantitative evidence, another model that also includes qualitative evidence would provide a richer source of information that hospital executives and nursing administrators could access to address complex questions and issues involving the care practice, interventions, and the impact of the interventions on care providers and patients in relation to fall prevention. Finally, the efficacy of the proposed model should be validated in future studies that establish a structured strategy of incorporating lessons-learned through testing, transforming, and integrating the model within clinical practice guidelines.

4.2 CONCLUSIONS

4.2.1 Implications for Research

While identifying clinically significant evidence that demonstrated the effects of the physical environment on falls, fall-related injuries, and intermediate patient outcomes associated with falls (i.e., postural sway and hip impact force), well-documented empirical studies that test the relationships between the physical environment and falls and fall-related injuries were very limited. Many of the articles were excluded from this study because they did not meet the inclusion criteria even though they offered an overview of environmental factors and underlying mechanisms that link the environment to such outcomes.

Several environmental factors have shown promise at reducing falls or fall-related injuries: 1) Nuclear unit layouts and acuity-adaptable rooms with decentralized nurses' stations relate to a reduction in the number of falls; and 2) carpeted flooring and carpeted flooring with wooden sub-flooring correlate with a decline in the severity of fall-related injuries. These conclusions apply both to new construction and to hospitals facing the replacement or renovation of their aging facilities. Further studies are needed that establish a structured process model that can guide hospital executives and nursing administrators to incorporate certain environmental factors during certain stages of hospital planning and construction.

Several hospitals have implemented easy-to-apply interventions (e.g., the relocation of at-risk patients close to nurses' stations and identification bracelets) as part of their multi-faceted strategies (See Table 3), but the review identified no solid evidence demonstrating the efficacy of such individual interventions on the reduction of falls and injuries. On the other hand, although it identified clinically significant evidence of the efficacy of some interventions (e.g., medication review/modification and volunteer programs) at reducing falls in related settings, it found that they have been widely adopted in hospitals.

This review identified several effective single interventions that hospitals should consider as part of their multifaceted fall prevention intervention: 1) medication review and modification, 2) patient education, 3) volunteer programs, and 4) bedrail reduction programs; and it clarified the need for further studies that could provide conclusive evidence on the efficacy of specific single interventions (i.e., environmental assessment/modification, hip protectors, and footwear) that have proven effective in reducing the falls and injuries of long-term care or community-dwelling elderly populations but not of hospital inpatient populations.

4.2.2 Implications for Nursing Practice

A multi-systemic fall prevention strategy that takes into account the benefits of physical environment-related interventions/factors in fall prevention could more efficiently address both intrinsic and extrinsic/environmental fall risk factors and therefore prevent falls and assure a safe and supportive environment that is not only efficacious to fall prevention but also beneficial to the well-being of patients and caregivers. Thus, hospitals need to recognize the significant role of the physical environment in fall prevention and incorporate environment-related interventions into their multifaceted fall prevention intervention programs. The multi-systemic fall-prevention models can assist hospital executives and nursing leaders with the development of a balanced fall prevention strategy that benefits from the collective effects of the physical environment, the care process and culture, and technology to prevent falls and fall-related injuries. The acquired evidence base in the efficacy of environment-related interventions/factors will be useful to many hospital executives and nursing administrators as they go through different stages (e.g., the new construction, renovation, or replacement) of hospital planning and construction.

CHAPTER 5

RESEARCH OUTLINE

5.1 Introduction

Although the fundamental link between physical environmental factors and falls has been established, the emerging evidence is limited to the investigation of only a few architectural design factors such as a certain unit layout (radial units) or a patient room layout (acuity-adaptable rooms) and flooring. Furthermore, the literature relevant to unit and room layouts identified only the association of a certain unit and patient room layouts with a reduction in patient falls, but did not fully explore what environmental measures or mechanisms (e.g., visibility and accessibility to patients) associated with those unit and patient room layouts contributed to the outcome. Therefore, the purpose of the current study is to gain a systematic understanding of physical environmental measures or factors that can be determined by unit and room layouts and to identify significant physical environmental factors associated with patient falls.

The environment (Dublin Methodist Hospital) of the current study provided a special opportunity to identify a range of physical environmental factors bound to unit and room layouts and their impact on patient falls because the physical design of all patient rooms was nearly identical with only a few exceptions. Having nearly identical patient rooms provided internal controls on certain environmental factors (e.g., the type of flooring, the size of the room, and the location of handrails) that may affect patient falls. In addition, the study environment offered three identical inpatient units with patients similar in their medical conditions (i.e., medical-surgical patients). This allowed the sample size to be tripled to include fall data from patients in all three of those units, while still being able to control the impact of other unit layout-related design factors (e.g., centralized or decentralized nurses stations) on the outcomes (i.e., patient falls). In other words, the study environment offered internal controls for both unit and room layouts and, therefore, the current study could fully investigate the impact of environmental factors such as visibility, accessibility, or distance to a patient.

Working with both the clinical and environmental aspects of inpatient falls, the current study identified critical physical environmental factors, associated with unit and room designs, that increased the probability of a fall while adequately controlling for clinical factors and other environmental factors that might mask the impact of the physical environment on the outcomes of interest.

5.2 Aims and Significance

The purpose of the current study is to gain a systematic understanding of environmental measures or factors that can be determined by unit and room layouts and to identify significant environmental factors associated with patient falls.

In recent years, the need for hard evidence that links certain design factors to inpatient falls and fall-related injuries has become more imperative to an increasing number of healthcare providers as they face the need to replace their aging 1970s hospitals. In fact, the healthcare industry in the United States will spend more than $180 billion for new hospitals in the next five years alone, and healthcare construction is projected to exceed $70 billion per year by 2011 (Jones, 2007). These new hospitals will remain in place for decades and shape medical care in the next generation. Given the magnitude of investment and considering the substantial impact of the new infrastructure on the safety and quality of the care of our next generation, it is important that we actively seek solid evidence that will help us create physical environments that promote healing and lead to improved outcomes, safety, and efficiency. The findings from the current study can inform healthcare leaders, architects, and planners of specific design decisions that will reduce inpatient falls within their organizations for the next 50 to 60 years.

5.3 Research Design

This research utilized a case-control study design that compares individuals (cases) who have a specific disease or an incident (e.g., a patient fall) to individuals (controls) who do not with the aim of identifying risk factors associated with a specific incident. The study utilized a retrospective patient medical and incident data review and physical environment assessment procedures (See the Section 5.6.1 Data Collection Procedures for details). The investigator retrospectively reviewed fall incident data for the past three years at Dublin Methodist and then identified fallers (the case group) and collected their fall-related characteristics (e.g., age, gender, admitting diagnosis, DRG, Length of stay at time of falling and mobility, mentation, elimination, fall history, current fall-related medication, total fall risk score from the fall risk screen) from patient medical records. Based on the fallers' fall-related characteristics, the investigator identified non-fallers (the control group) who have an intrinsic profile similar to fallers but who did not sustain falls. Once the investigator identified both the faller and the non-faller groups, we identified their physical care locations (i.e., patient room locations) and assessed environmental factors associated with both patient groups, by using floor plans, a newly-developed fall environment assessment tool, and appropriate spatial analysis software (i.e., AutoCAD and Depthmap) during facility assessments or off-site floor plan analyses.

5.4 Study Environments and Participants

This case-control study of patients with a recorded fall was conducted at Dublin Methodist Hospital, Dublin, Ohio, a 100-bed acute care facility. The Dublin Methodist Hospital (DMH) has five inpatient units (three medical-surgical, one Labor/Delivery, and one

Mother/Baby units). A total of 94 inpatient falls were reported from the five inpatient units at DMH between January 08, 2008 and January 07, 2011. The study included only inpatient falls, excluding falls by visitors and staff. The 94 inpatient falls occurred among 92 patients, 2 of whom fell twice and 4 of whom were patients of Labor/Delivery and Mother/Baby units. All 94 inpatient falls occurred in patient rooms. We analyzed only the first falls by 88 medical-surgical patients. Figure 5.1 presents pictures of the three medical-surgical units under study at DMH. We excluded the four falls sustained by patients in the Labor/Delivery and Mother/Baby units and the two second-time falls sustained by the medical-surgical patients to reduce bias for patient characteristics. For a comparison, we selected one to three control subjects who had a similar profile (i.e., age, gender, admitting diagnosis, and DRG) as each of the fallers but who did not sustain a fall from the total population of inpatients admitted to the hospital during the study period. This resulted in a total of 148 controls.

This study was reviewed and approved by both the Georgia Institute of Technology and Dublin Methodist Hospital Institutional Review Boards.

Figure 5.1 Pictures of Medical-Surgical Units at DMH

5.5 Hypotheses

This study examines the following overall hypothesis: certain environmental factors, generated by unit and room layouts (e.g., visibility and accessibility to a patient, distance from medication to a patient, or bathroom location in relation to a patient) are associated with an increase or a decrease in the probability of experiencing a fall. Specific hypotheses are as follows. Specific definitions and descriptions on the physical environmental factors tested in the study will be provided in the section 5.9 Study Variables.

- **Visibility I**: The less spatial area in which a patient is visible within unit, the greater the probability of falling for the patient. In other words, patients with less spatial areas, in which the patients are visible within unit, will have greater probability of falling than those with greater spatial area, in which the patients are visible within unit. Having less spatial area in which the patients are visible may be associated with less opportunity to for caregivers to maintain visual access or surveillance to patients and, therefore, reduce caregivers' ability to intervene in situations where a fall appeared likely to occur.

- **Visibility II**: Patients who are not visible from a nearby decentralized nurses' station but only from a corridor will have greater probability of falling than those visible not only from a nearby decentralized nurses' station but also a corridor. This measure is different from the first visibility measure (Visibility I) to the extent that this measure takes into account the functional aspects of the area in which a patient is visible. Among patients who are visible from similar spatial areas in a unit, , it is hypothesized that those who are visible from a nearby decentralized nurses' station will have a lower risk of falling due to the inherently higher level of surveillance possible, leading to a greater chance of staff intervention before a fall, as opposed to other patients who are mainly visible from corridors only.

- **Accessibility**: The least accessible patients have a greater probability of falling than those who are highly accessible. In other words, if the patient is placed in the area that is least accessible from any other part of the unit, that patient will have a greater probability of falling. Being segregated or being less accessible may be associated with having fewer caregivers in the immediate area who could respond to the patient in a timely manner in situations where a fall appeared likely to occur.
- **Distance to medication:** Patients far from medication areas have a greater probability of falling than those close to medication areas. The locations of certain functional spaces like the medication areas also affect where caregivers tend to congregate, in addition to the overall layout of the unit, which determines the overall pattern of caregivers' presence in the unit and the relative accessibility to each patient. Therefore, distance to the functional space (i.e., the medication area), identified through observation as the busiest area in the unit makes a difference. Patients who are far from a medication area will be subject to less visual surveillance and proximity to caregivers, both of which provide opportunities for caregivers to intervene in situations where a fall appears likely to occur.
- **Bathroom location**: Patients whose bathroom is located on the footwall side will have a greater probability of falling than those whose bathroom is located on the headwall side. Having the bathroom located on the footwall side will increase the distance a patient must walk without the handrail support. Healthcare design experts suggest that a bathroom on the headwall side may be associated with a reduction in patient falls for several reasons: being on the same wall potentially reduces the distance from the patient bed to the bathroom and makes it easier to install continuous handrails from the bed to the bathroom door.

- Lastly, all the environmental factors listed above play their roles simultaneously**.** Therefore, it is important to test the impact of each variable when acknowledging (or controlling for) the impact of other environmental factors. The study hypothesized that being visible from a nearby decentralized nurses' station (Visibility II) and being highly accessible would be dominant factors associated with patient falls which means that those will remain as significant factors when the impact of other environmental factors (i.e., distance to medication and bathroom locations) is considered.

5.6 Data Collection Procedures

5.6.1 The Retrospective Patient Medical and Incident Data Review: Fallers Data Collection

The investigator, with assistance from hospital staff, pulled relevant variables (see Table 5.2) from medical and incident records for fallers (patients who sustained falls between January 8, 2008 and January 7, 2011) and entered the data into secured excel files.

5.6.2 The Retrospective Patient Medical Data Review: Non-fallers Data Collection

The investigator, with assistance from hospital staff, pulled relevant variables from the records of all the inpatients admitted to the hospitals listed above between January 8, 2008 and January 7, 2011and exported them to secure electronic files. To minimize the burden on the hospital staff, we initially collected a limited set of fall-related patient variables from all patients admitted between January 8, 2008 and January 7, 2011: 1) a patient account number, 2) an admission date, 3) a discharge date, 4) a patient room number, 5) age, 6) gender, 7) admitting diagnosis (number and description), and 8) MS-DRG (number and description).

With this data, the investigator first identified fallers within the data set and excluded them. Then, inpatients were selected who fit a similar profile but who did not experience a fall during their stays (the control group), using the fallers' fall-related characteristics comprised of the variables of age, gender, admitting diagnosis, and DRG. The control group needed to be between 100% and 300% of the size of the fall group. Therefore, the investigator selected one to three non-fallers per faller. Procedures relevant to the selection were the following: 1) the investigator first identified non-fallers with the same admitting diagnosis and DRG as the faller, 2) among selected non-fallers, the investigator identified non-fallers who were of the same or similar age (± 10 years) as the faller, and 3) the gender and the length of stay of the faller were further considered as factors in choosing three or fewer comparable non-fallers.

Once the control group (N = 148) was identified, the investigator, with assistance from hospital staff, pulled additional fall-related variables (i.e., mobility, mentation, elimination, fall history, and total fall risk score) (see Table 5.2) from the patients' medical records and entered the data into secured excel files.

5.6.3 The Physical Environment Assessment

The investigator collected facility-based data by annotating existing floor plans on-site and analyzed the floor plans with spatial analysis software (i.e., AutoCAD and Depthmap) to delineate and document environmental factors associated with each faller and non-fallers' location (i.e., visibility and accessibility to patient, distance to medication, and bathroom location). AutoCAD is a type of design drafting and documentation software that allows the investigator to use floor plans to analyze and calculate the size of patient rooms or patient bathrooms and the distance from a patient room to a nurses' station or from a patient bed to bathroom s. Depthmap is a computer program that performs visibility analysis on architecture. It takes input in the form of a plan of a building and is able to construct maps of the visual field, using numeric visibility measures, at points within the buildings.

5.7 Study Variables: Fall-related Patient Variables

Fall-related patient variables were collected so that their impact on the outcome of interest could be controlled for (i.e., patient falls) (See Table 5.2). The variables are as follows: patient account number, fall report data, fall incident time, unit location, patient room number, physical location, age, gender, admitting diagnosis (description and number), diagnosis- related group (DRG), length of stay (LOS), mobility (i.e., ambulates without problems, unable to ambulate, ambulates with assistive device, and ambulates unsteadily), mentation (i.e., alert, unresponsive, periodic confusion, and always confused), elimination (i.e., independent, independent with frequency, needs assistance, and incontinent), prior fall history (i.e., none, unknown, yes before admission), current fall-related medication (i.e., none, anti-convulsants, tranquilizers, psychotropics, and hypnotics), total fall risk score (total score weighed from five fall-related characteristics: mobility, mentation, elimination, prior fall history, and current fall-related medication). The length of stay (LOS) had been collected at the time of falling for fallers and, then, the fallers' LOSes were used to identify the appropriate data to collect about non-fallers. In other words, if a faller fell in the fourth day of his or her stay, a comparable non-fallers' fall-related characteristics were collected around the fourth day of their stays. This procedure controls for the impact of differences in the LOS on patient falls.

5.8 Study Variables: Care Process-related Variables

Earlier sections reviewed the risk factors that directly contribute to inpatient falls. Literature identified that falls occur through a complex interaction of intrinsic (patient-related) and extrinsic (environment-related) risk factors. Studies have also identified some factors that help prevent inpatient falls. In other words, various fall prevention strategies currently in place in hospitals (from the environment-, care process-, to technology-related interventions help reduce or mitigate the direct causes of falls and, therefore, contribute to reducing or preventing falls. This indicates that the incidence of falls may be associated not only with direct causes (e.g., fall risk factors) but also the absence or insufficiency of interventions that can prevent falls. This observation indicates that the current study may need to control for the impact of such supportive measures already in place in the hospital in addition to control for the direct causes of inpatient falls (i.e., the fall-related patient data collected here). Without properly controlling for the effects of various fall prevention interventions among patient groups, the association between certain physical environmental factors and inpatient falls cannot be solely attributable to the environmental factors, because it is possible that these other variable shape the association between environmental factors and inpatient falls.

Because of these facts, this study attempted to control for the effects of fall prevention interventions applied to the patients under study. However, soon after initiating the investigation, several challenges emerged. First, up to 22 different fall prevention interventions were being implemented in the hospital. This large number of fall prevention interventions presented a statistical challenge. The more study variables, the more increased issues with multi-co-linearity or multiple co-dependences among variables, which might have biased the outcome. Second, the data in the nursing records regarding fall prevention interventions applied to patients was, in part, questionable because of inconsistencies. In some nursing records, nurses diligently checked all the check boxes to indicate fall prevention interventions applied to their patients. But, in others, fall prevention interventions that should have been provided regardless of the patient's fall risk score were, in many cases, not marked as "applied." Therefore, it was not clear whether those interventions were in fact not applied to the patients, or whether the forms were filled out incorrectly due to the challenges of checking all those boxes.

Due to the limitations of performing an investigation that attempts to individually evaluate fall prevention interventions per patient and to statistically control for them, the impact of fall prevention interventions was methodologically, rather than statistically, controlled for in this study. In other words, the methodology of selecting non-fallers who have a similar intrinsic profile as fallers reduces differences in patient characteristics and, in turn, reduces differences in fall prevention interventions applied between the patient groups because the fall prevention policy and relevant procedures (See Appendix A and Table 5.1) at DMH were designed to provide similar fall prevention interventions to patients with a similar intrinsic profile or fall risk scores. The fall prevention policy at DMH provision that any patient who receives a score of three (3) or higher on the Fall Risk Assessment is deemed to be at risk for falls, and, then, additional fall prevention interventions are applied for those at risk. This means that the kinds of fall prevention interventions stay similar among low risk patients as they do among high risk patients. In addition, among patients deemed to be at risk, if a patient displays issues with his or her mentation, mobility, and elimination, some individualized interventions will be implemented. Table 5.1 compares fall prevention interventions applied to all patients (regardless of their total fall risk scores) and to patients deemed at risk, based on the fall prevention policy at DMH (Appendix A). Table 5.1 also presents procedures relevant to individualized interventions, depending on a patient's certain fall-related conditions: 1) for patients with confused or /altered mental status, consider pharmacy consult for medication evaluation, low bed, bed alarm, diversional activities, move patient closer to station; 2) for patients with altered mobility, consider requesting consult for PT/OT; stay with patient during toileting; and 3) for patients with altered elimination, provide bedside commode, provide toileting opportunity at least every 2 hours.

In fact, findings of correlation analyses between various variables and the patient group (as it is presented in detail in Table 6.2 in the Chapter 6) identified no statistically significant difference in the total fall risk score between the two groups. Considering the fact that the falls prevention policy at DMH differentiates the kinds of falls prevention interventions to be applied to each patient, depending on his/her total fall risk score, similar average fall risk scores between the two groups could imply similar fall prevention interventions applied to the two groups. However, the analysis also identified a statistically significant difference in two categories of the patient mentation (i.e., alert and periodic confusion) between the faller and the non-faller groups. Less alert or more periodically confused patients existed in the faller group. This indicates that more supportive measures (or fall prevention interventions) might have been applied to the two categories of patients in the fall group.

In conclusion, based on the similar fall risk scores between the two groups, it is likely that, overall, the kinds of fall prevention interventions applied to patients are similar between the two groups. Even though certain categories of patients (i.e., ones with periodic confusion) in the faller group might have been provided with more preventative interventions, fell anyway, and so it is also safe to say that it was not better access to interventions that led to the non-fallers ability to avoid falling. Therefore, we concluded that it is not necessary statistically to control for the impact of fall prevention interventions on inpatient falls in this study.

Table 5.1 Comparison of Fall Prevention Interventions Applied to All Patients and Only to Patients at Risk

Fall Prevention Interventions in Place at DMH	
For All Patients (Regardless of Their Total Fall Risk Score)	For Patients at Risk
1. Orient patient to person, place, time, and environment, physical set-up of room and use of call light. Reorient patient as needed. 2. Provide clear instructions regarding mobility restrictions, proper ambulation and transfer techniques. 3. The environment should be maintained for safety: 4. The normally used pathways in the patient's room will be free of clutter which may pose obstacles to safe ambulation (IV poles, over bed tables). 5. The floors will be clean and dry – spills will be cleaned immediately. 6. The patient will have ready access to equipment needed for toileting (urinal within reach, bedside commode in position). 7. Bed and equipment locked. 8. Necessary objects will be in easy reach of patient (call light, over bed table with water pitcher). 9. Adequate lighting will be maintained. 10. Patients should wear non-skid footwear at all times unless contraindicated.	1. Place visual identifier on the patient's medical record to communicate the risk for falls; place fall magnet in patient's room or on door frame. 2. Visual reminder to ask for assistance will be posted at the bedside in the patient's line of vision. 3. Encourage visiting family members to provide companionship, call for help or assist with ambulation and follow interventions to prevent falls. 4. Staff will observe patient at risk for falls at least every 2 hours. 5. Implement individualized interventions, based on the reason the patient is at risk for falls: Confused/altered mental status (e.g. Consider pharmacy consult for medication evaluation, low bed, bed alarm, diversional activities, move patient closer to station) Altered mobility (e.g. Request consult for PT/OT; stay with patient during toileting) Altered elimination (e.g. Provide bedside commode, provide toileting opportunity at least every 2 hours). 6. Physical restraint may be used to prevent a patient from falling as a last resort, and only after all other methods have proven to be

11. Staff should provide for toileting of patients at regular intervals, especially at bedtime. 12. Bed height will be maintained in the lowest position at all times except when care is being delivered. 13. Side rails may be used to assist the patient with positioning. Upper side rails only should be used for this purpose. Side rails are never used to prevent the patient from exiting the bed.	ineffective. Patients will not be physically restrained as a result of experiencing a fall unless all other interventions have been attempted and failed. If physical restraint is necessary to prevent a patient from falling, refer to SPP P-105-DBHSP Use of Restraints. 7. Alterations to the Plan of Care should be considered by the Registered Nurse in the event of changes in the patient's condition, ineffective interventions, and/or undesirable outcomes. 8. In the event a patient experiences a fall, an Unusual Occurrence report will be submitted. 9. In the event a patient experiences a fall, the RN will do one of the following: If the patient is competent to make decisions for oneself, the RN should recommend to the patient that he/she notifies his/her next of kin (primary person listed on face sheet) of the event. If the patient is not competent, or otherwise impaired, the RN should notify the next of kin as soon as appropriate before the end of the shift.

5.9 Study Variables: Physical Environmental Variables

5.9.1 Visibility to Patient (Visibility I and II Measures)

5.9.1.1 <u>Visibility and Patient Falls: Why Does Visibility Matter for Patient Falls?</u>

Visibility to patients is inherently important in good patient care. It promotes on-going visual surveillance, awareness of the patient's situation and the situation around the unit, and the timeliness of care. A majority of patient falls occurs while patients are ambulating on their own, without assistance from staff. This was evident in current study, which identified that 78 out of

88 falls occurred when staff was not there to assist the patients. Patients get out of their beds without assistance for many reasons. Those are as follows: 1) patients simply think that they can do the activities by themselves and, therefore, do not ask for help, 2) in many cases, patients are confused or not in an alert state, because of the medications they are taking and/or other medical reasons 3) in some cases, even though patients remember to call for help, staff do not arrive in a timely fashion and so patients take matters into their own hands. The lack of visual connection between the patient and the staff, in many cases, considerably limits the patient's ability to reach out to staff, so that patients are dependent upon auditory signals such as their own voices or nurse button signals. The lack of visual connection also raises the issue of the level of awareness of patients from the staff's point of view and awareness of staff from the patient's point of view. Staff is not always fully aware of what is going on with the patient and *vice versa*. Therefore, the lack of visual connection may easily cause patient frustration when their calls do not receive a timely response and, therefore, the patient may get out of bed without further waiting. The emerging understanding of relevant fall circumstances and challenges in fall prevention has highlighted the importance of surveillance, awareness, and timeliness in the prevention of patient falls, and emphasizes how improved visibility can promote these important organizational functional aspects (i.e., surveillance, awareness, and timeliness) of hospitals that will lead to the improvement of hospital safety (See Figure 5.2). Figure 5.2 presents a conceptual model that emphasizes the impact of visibility on certain organizational functioning (i.e., surveillance, awareness, and timeliness) that will contribute to fall prevention.

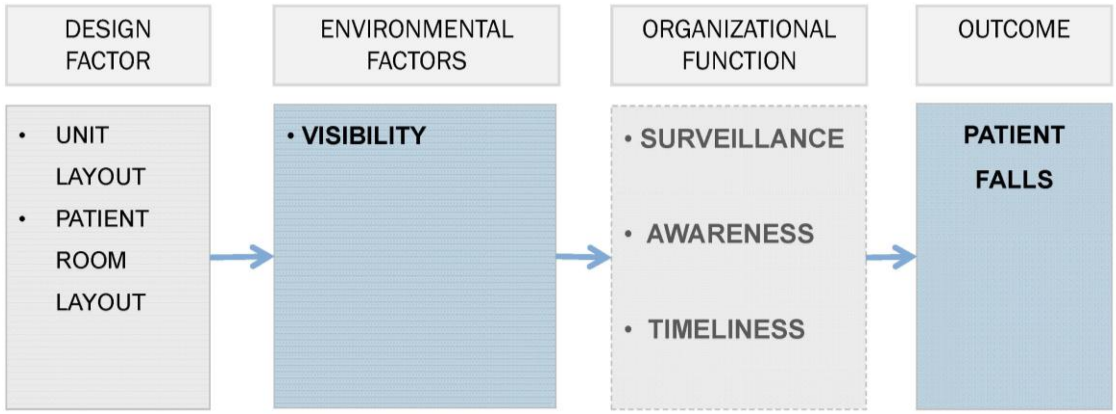


Figure 5.2 Visibility-Organizational Function Model

In fact, there is growing evidence that demonstrates the role of the physical environment and architectural design factors in improving organizational functioning such as surveillance, peer and situation awareness, and timeliness (Cai & Zimring, 2011; Hall, Kyriacou, Handler, & Adams, 2008; Leaf, Homel, & Factor, 2010; Vassallo, Azeem, Pirwani, Sharma, & Allen, 2000) (See Figure 5.3). The current study also aims to promote a better understanding of the relationship between visibility and organizational functioning as linking visibility to the key safety outcome (i.e., patient falls) of hospitals. In addition, emerging evidence also established the direct association between visibility and patient-related outcomes (i.e., patient falls and mortality rates) (Hendrich, Fay, & Sorrells, 2004; Leaf, Homel, & Factor, 2010; Vassallo, Azeem, Pirwani, Sharma, & Allen, 2000) (See Figure 5.4). The current study aims to contribute to the understanding of the impact of the physical environment, especially visibility, on patient safety.

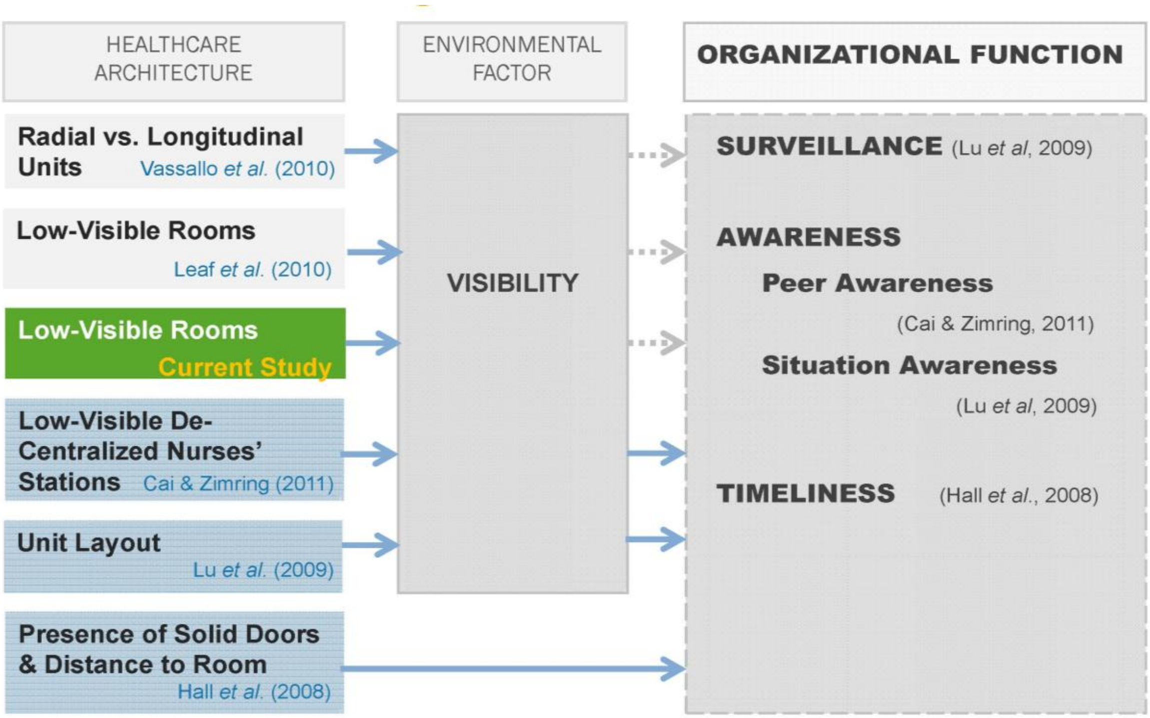


Figure 5.3 Healthcare Architecture, Visibility, and Organizational Function

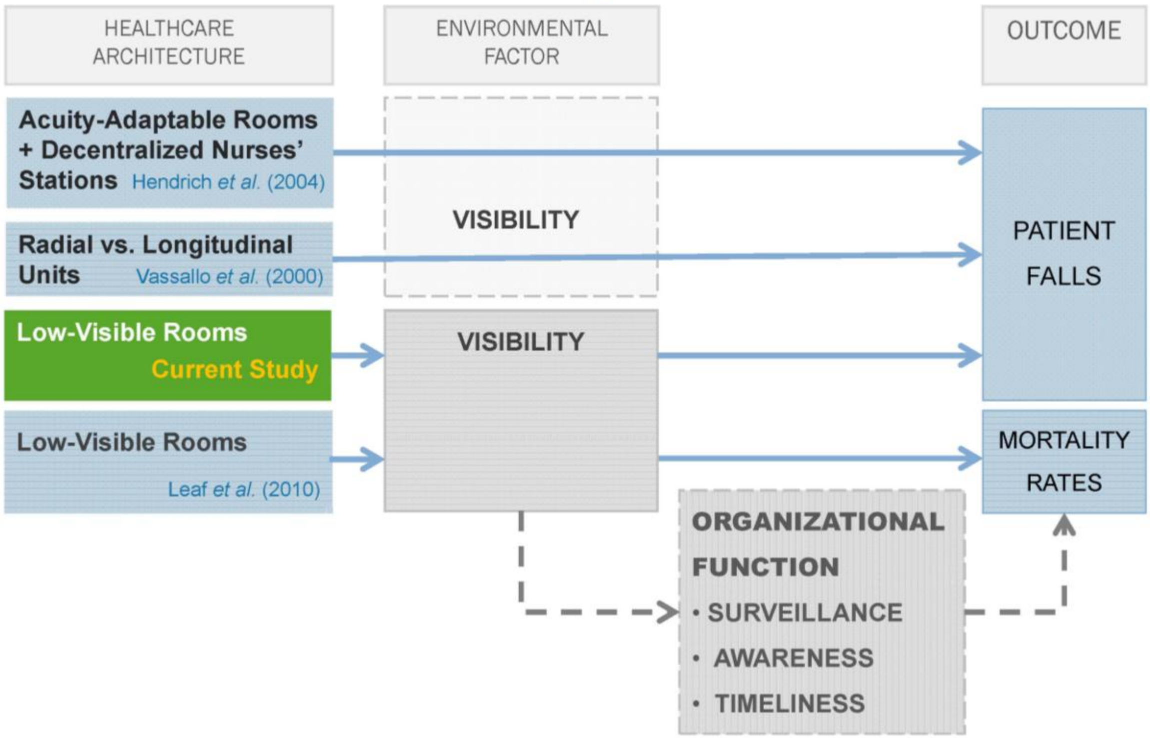


Figure 5.4 Healthcare Architecture, Visibility, and Patient Safety

5.9.1.2 <u>Visibility to Patient: Definition and Process</u>

This study developed two different measures of patient visibility: Visibility I, the area in which each patient is visible from within a unit and Visibility II, whether or not each patient is visible from the nurses' stations and corridors. The first visibility measure (Visibility I) is related to the assumption that having less spatial area in which a patient is visible, might be associated with an increased probability of falling due to the diminished opportunity that caregivers have to maintain visual access to patients. This first measure only concerns the magnitude of the area and does not take into account the operational functions of the area, which can also be critical for fall prevention. Therefore, another visibility measure (Visibility II) was developed that accounts for kinds of functional spaces that the visible area might cover (see Table 5.2). For example, the areas from which some patients' are visible could overlap a nearby decentralized nurses' station area, which means that the patients are visible from that nurses' station. On the other hand, some areas from which patients are visible might only overlap with corridors. A hypothesis of this study is that that the functional spaces from which a patient is visible matter more than the magnitude of the area from which a patient is visible. In other words, being visible from key functional spaces (e.g., a nearby decentralized nurses' station) will be more important than having a large area within a unit from which a patient is visible, at least when it comes to fall prevention. Therefore, among patients with a similar amount of area from which they are visible, it is the hypothesis that patients who are visible from a nurses' station will have a lower probability of falling than patients who are visible only from corridors or not visible even from corridors.

5.9.1.3 Visibility I: Definition

Visibility I can be measured in several different ways, depending on how one defines patient visibility. For example, when you measure the visible area, would you include an area in which you can see the patient's foot or only the patient's head? This study developed two different measures for Visibility I, measuring visibility from two different points to understand which measure better explains the probability of falling. The first Visibility I measure (Visibility1_head area) was from points in which a patient's head resides. In other words, this measure does not include any areas within a unit from which you can see a patient's abdomen or foot. The second visibility I measure (Visibility1_body area) was from several points in which a patient's body resides (visibility body). Therefore, this particular measure includes areas in which any parts of a patient's body (e.g., a foot) are visible. It is hypothesized that the magnitude of the area in which a patient's head is visible will matter more than the magnitude of the area in which any part of a patient's body is visible, and will be more significantly associated with inpatient falls than the other two visibility measures.

5.9.1.4 Visibility I: Process

The areas of Visibility I were calculated by a computer program called Depthmap (Turner, 2010). This program uses an architectural representation of a floor plan in the AutoCad format as an input and overlays small square tiles (for example, one foot by one foot) on the floor plan. The program counts all the tiles that it can reach from any particular tile with straight lines without going through boundaries such as walls. These counts are calculated as visibility (Peponis et al., 2007). An actual graph of visibility analysis for one of the units (i.e., unit 3200) is shown in Figure 5.5, where color ranges from red to blue represent values from high to low. To run visibility analyses, the AutoCAD floor plans were prepared to include only lines (e.g., full height walls, doors, or furniture) that that can obstruct a person's visual line of sight. The lines that do not obstruct visual access were saved in a different layer of the floor plans so that they can be visualized after the visibility analyses for a better understanding of the floor plans. An example of visibility analysis for one patient (from areas, in which the patient's head resides) in the room 3201 is shown in Figure 5.6.

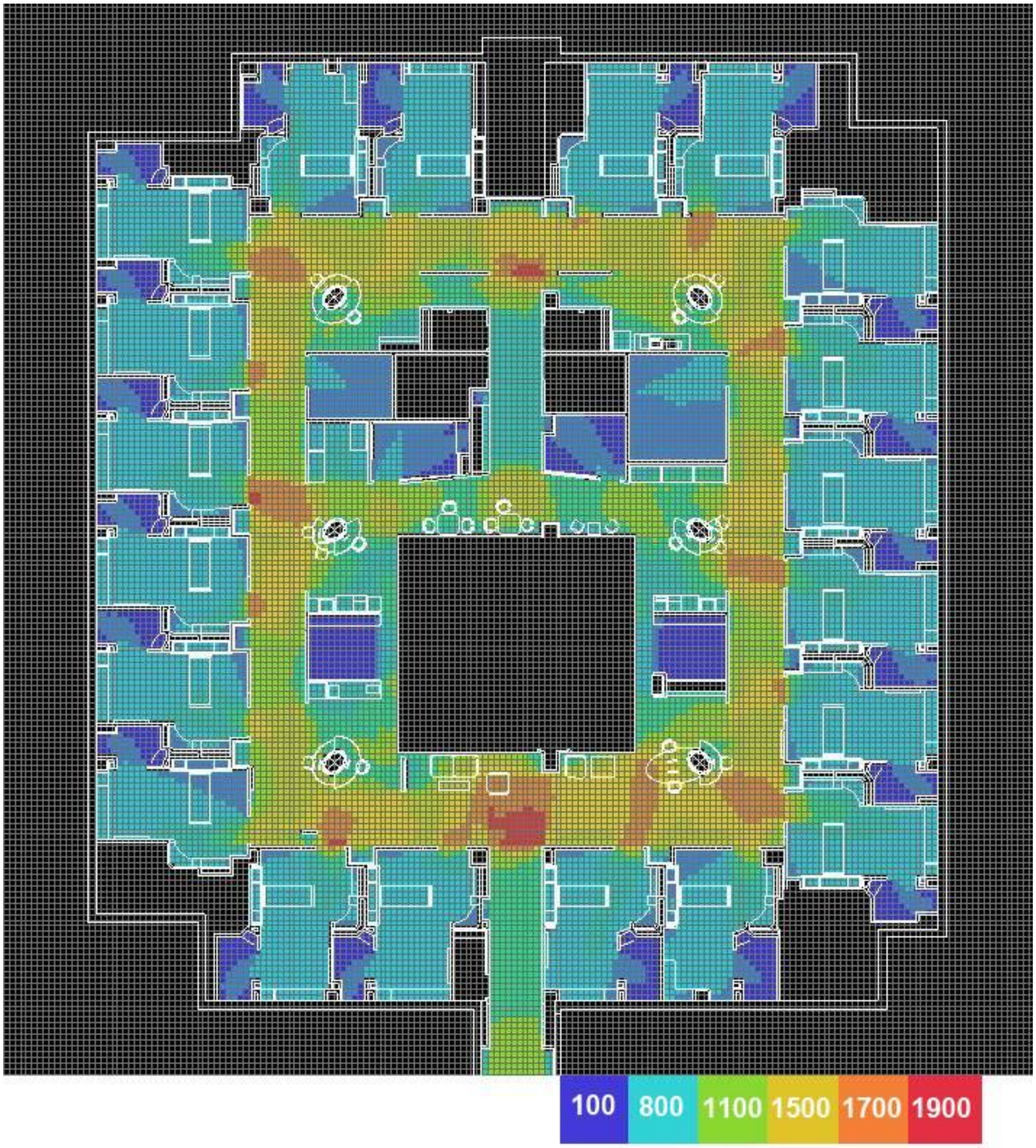


Figure 5.5: Analysis of Visibility (Unit 3200)

Figure 5.6: Analysis of Visibility I for the Patient (from the Head) in Room 3203

5.9.1.5 Visibility II: Definition and Process

Visibility II can be also measured in a number of different ways, depending on different assumptions. We could define a patient as being visible from a nearby decentralized nurses' station with the following three assumptions: 1) when a patient's head is visible from any given point of the nearby nurses' station (Visibility2_head_nurses station), 2) when a patient's head is visible from designated seats in the nearby nurses' station, allowing a 360 degree visual angle

(Visibility2_head_seats_360), and 3) when a patient's head is visible from designated seats in the nearby nurses' station allowing only a more realistic 210 degree visual angle (Visibility2_head_seats_210) with the seating oriented in its intended direction. On the other hand, we could define visibility as a patient being visible from a nearby decentralized nurses' station when any part of the patient's body is visible from any given point in the nearby nurses' station (Visibility2_station) or when any part of the patient's body is visible from designated seats in the nearby nurses' station, allowing a 360 degree visual angle (Visibility2_body_seats_360), or, finally, when any part of the patient's body is visible from designated seats in the nearby nurses' station with realistic 210 degree visual angle (Visibility2_body_seats_210). Using different assumptions, six different measures of Visibility II (See Table 5.2) were developed, and those have been tested to understand which measure fits best when predicting the probability of falling.

The hypothesis is that it will be more important that a patient is visible from designated seats at a nurses' station with a 210 degree visual angle, and with seating oriented as intended than being visible from any part of nurses' station or from designated seats at a nurses' station with a 360 degree visual angle. Figure 5.7 shows pictures of medical-surgical units that present various conditions of visual access to patient rooms. Some offer a complete visible access to a patient (or a patient's head area) from a seat in a nearby decentralized nurses' station and some did not offer any visual access to a patient.

Figure 5.7 Various Visibility to a Patient from a Designated Seat in a Nearby Decentralized Nurses'Station

5.9.1.6 Visibility II: Three Patient Groups

Depending on where a patient room is located in relation to key functional spaces such as decentralized nurses' stations, a patient has a varying level of visibility compared to other patients in the same unit. As shown in Figure 5.8, some patient rooms offer almost complete visibility to patients' heads or bodies from the seats at decentralized nurses' stations (assuming a 210 degree visual angle from the seats) as opposed to other rooms that offer no visual access to patients' heads. Furthermore, as shown in Figure 5.9, some patient rooms do not even offer visual access to the patient's head from adjacent corridors, at least when considering a normal pattern of walking through the corridors. As incorporating these two different visibility analyses, the investigator first categorized each patient room into one of the three groups: 1) high-visible rooms: patients in the rooms are visible from both a nearby decentralized nurses' station and a corridor; 2) moderate-visible rooms: patients in the rooms are visible only from corridor (not from a nearby decentralized nurses' station); and 3) low-visible rooms: patients in the rooms are not visible at all from outside (neither from a nearby decentralized nurses' station or from a corridor). Figure 5.10 illustrates three different patient room groups mapped on floor plan: high-visible, moderate-visible, and low-visible rooms.

Then, depending on a patient's room categorization (i.e., high-visible, moderate-visible, and low-visible room), patients were also categorized into three group (i.e., high-visibility, moderate-visibility, and low-visibility patient groups). For example, a patient who sustained a fall (or cared) in the high-visible room is categorized into high-visibility patient group. A patient who sustained (or cared) in the low-visible room was categorized as low-visibility group. These sub-patient groups will be later compared during analyses to identify a group associated with higher risk of falling, presenting relevant environmental risk factor.

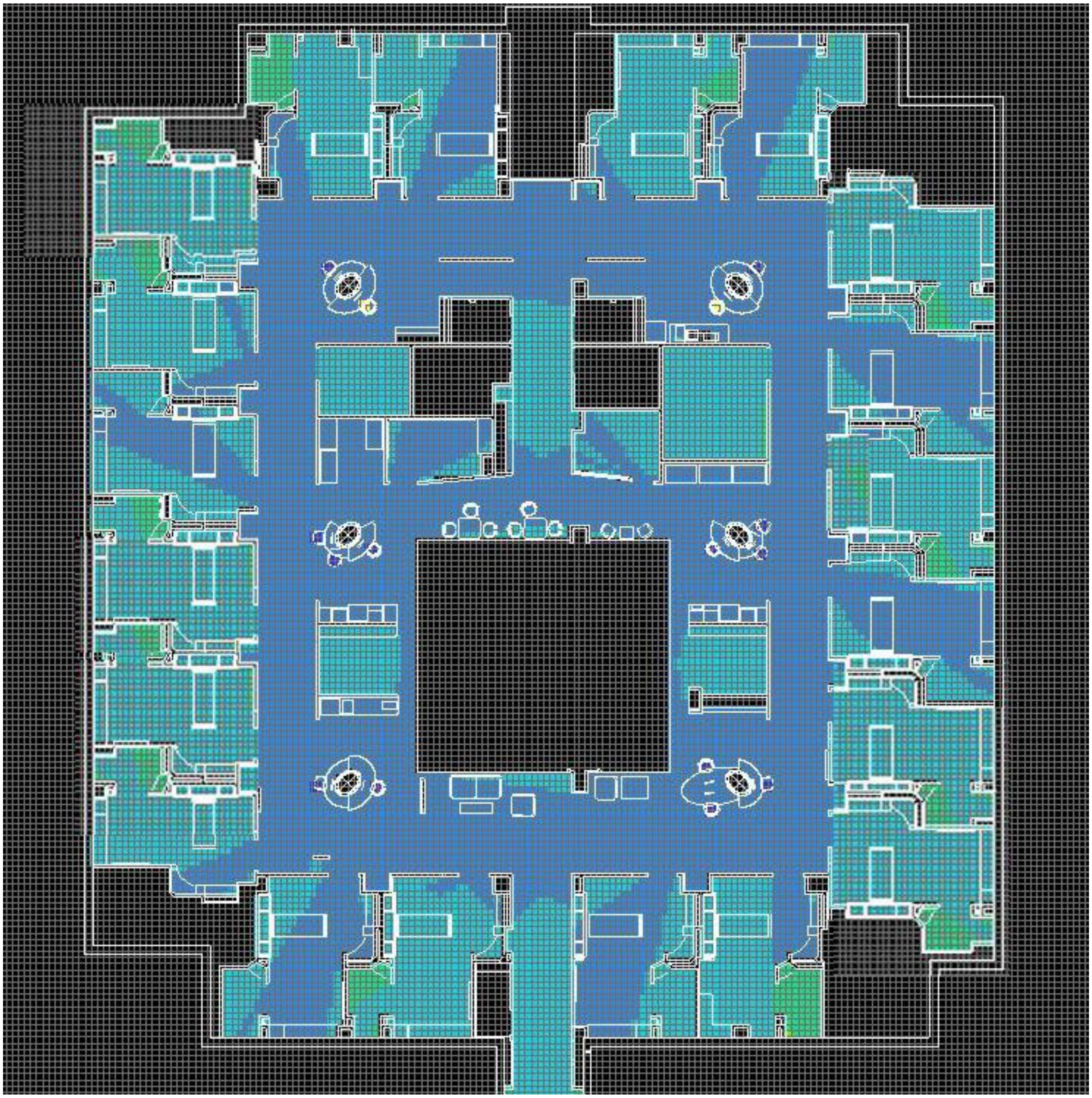


Figure 5.8 Analysis of Patient Visibility from Designated Seats at Nurses' stations (with a 210 Degree Visual Angle and with Seats Oriented for a Normal Pattern of Use). Spaces in Blue are Visible from the Seats.

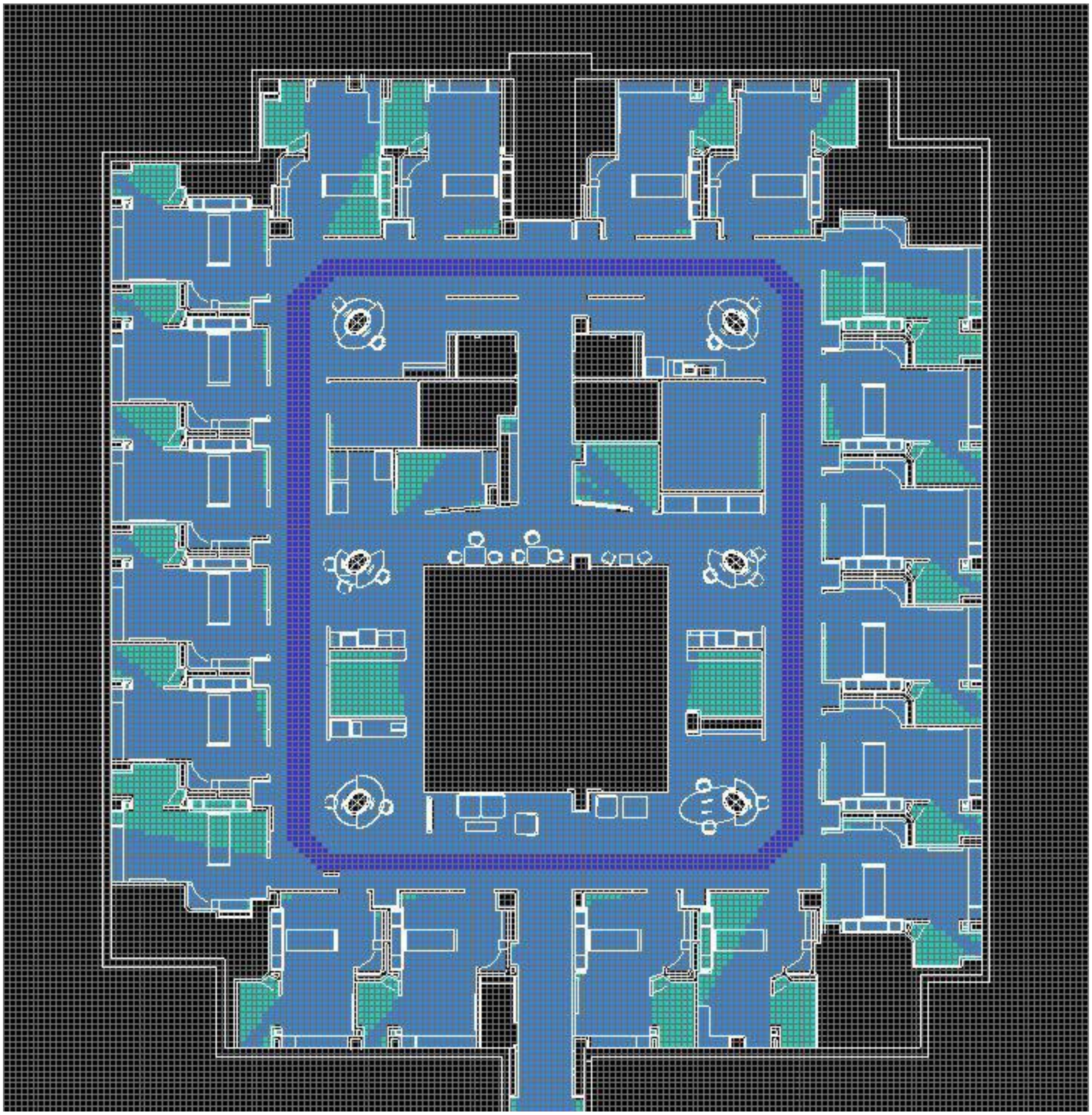


Figure 5.9 Analysis of Patient Visibility from Corridors, Considering a Normal Route of Walking. Dark Blue Indicates the Walking Path. Light blue Indicates Areas Visible from the Walking Path.

High-Visible Room
- Patients in the rooms are visible from a nearby decentralized nurses' station

Moderate-Visible Room
- Patients in the rooms are visible only from corridor

Low-Visible Room
- Patients in the rooms are NOT visible from corridor

Figure 5.10 Three Patient Room Groups in Visibility II measure

5.9.2 Accessibility to Patient

5.9.2.1 Accessibility and Patient Falls: Why Does Accessibility Matter for Patient Falls?

Better accessibility to patients is a desirable design aspect in patient care because it may promote on-going surveillance, awareness, face-to-face interaction, and timeliness through its impact on peoples' presence and physical distribution around patients. A considerable body of literature has demonstrated the significant roles played by accessibility, in addition to visibility, in the way that individuals perceive and use workplaces and communicate within them (Bill Hillier, 1996; Rashid, 2009; Rashid, Kampschroer, Wineman, & Zimring, 2006)

These previous studies have identified a striking correlation between the accessibility (or "integration") measure and the distribution of people in many different settings, including urban areas, offices, and healthcare settings (Hillier, Penn, Hanson, Grajewski, & Xu, 1993; Rashid et al., 2006). In particular, a study by Rashid et al. (2006) established positive correlations between accessibility (or integration) and several behavioral aspects (i.e., movement, copresence, and face-to-face interaction) in office settings. In simpler terms, the study found that there was more movement and copresence of people when a path or a space was highly integrated or accessible compared to when a path or a space was less integrated or accessible. In addition, the greater copresence in a path or a space due to its higher accessibility (or integration) was associated with greater face-to-face interaction. Therefore, it was assumed here that better accessibility to or around the patient would matter for patient falls because accessibility would increase the movement and copresence of people around a patient, that it would affect their interaction with a patient and, in turn, that it may increase the level of surveillance, awareness, and timeliness in responding to a patient's needs. Figure 5.11 illustrates the accessibility/organizational function model that attempts to describe the relationships between unit design, accessibility, behaviors, and certain aspects of organizational function.

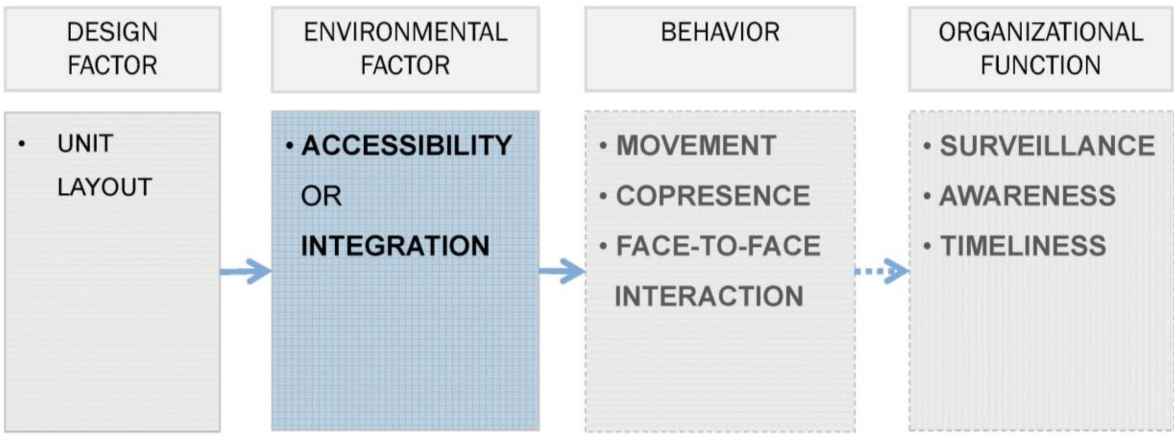


Figure 5.11 Accessibility-Organizational Function Model

5.9.2.2 <u>Accessibility: Definition</u>

The accessibility to a patient (or a patient's body) is measured by the average integration value of areas in which a patient's body resides. This method of measuring integration value of a space has been frequently used in architecture in the field of space syntax (Bafna, 2003; John Peponis, et al., 2007). The variable, accessibility to a patient, is defined as the average integration value of spatial areas in which a patient's body resides (See Table 5.2).

According to space syntax studies, "integration" is a measure of syntactical asymmetry (related to mutual depth) called RRA (Real Relative Asymmetry) (Hillier, Penn, Hanson, Grajewski, & Xu, 1993). The RRA, which is calculated for each space, is a ratio (Bafna, 2003). In this study, the space area was selected in terms of where each patient's body resides in each room. According to Bafna (2003), the RRA is computed by calculating the average "depth" of each node from all other nodes in the graph. This mean depth is then used to compute a number called

Relative Mean Depth or Relative Asymmetry (RA), which is the mean depth expressed as a fraction of the maximum possible range of depth values for any node in a graph with the same number of nodes as the system. Because depth is always positive and the mean depth of any given node can by definition never exceed the maximum range of a node in the system, RA values range from 0 to 1. This relativization makes it possible to compare RA values of nodes from graphs with different number of nodes. RRA is a ratio of the RA values of the nodes of the given system and the RA values of the central node of a *diamond* graph with the same number of nodes as the system. The diamond graph is characterized by an almost normal distribution of nodes across its levels and so has been found to represent a more realistic benchmark for comparing spatial settings of different sizes.

It is important to note that current space syntax studies typically report integration values which are the inverse of RRA values (1/RRA). Higher integration values of nodes, therefore, indicate that the node is less deep on average than all other nodes, or in other words, that it is more integrated into the spatial system. Integration value can easily be understood by putting into the context of accessibility to a patient. The variable accessibility to a patient is defined as the average integration value of the spatial area in which a patient's body resides (see Figure 5.12) within a system (or a unit). Higher values for accessibility to a patient indicate that the patient is located less deep on average from all other spaces in a unit, or in other words, that the location of the patient is more integrated within a unit.

5.9.2.3 <u>Accessibility: Process</u>

The accessibility to patient (the average integration value of areas, in which a patient' body resides) was calculated by the Depthmap program using floor plans as an input. An actual graph of integration for one of the units (i.e., unit 3200) is shown in Figure 5.12. Color values range from red to blue representing higher to lower value. To run integration analyses, the AutoCAD floor plans were prepared differently compared to the ones for visibility analyses. Like the visibility analyses that considered barriers to visibility, the software considered barriers to access. The accessibility floor plan analyses thus included all the lines that can obstruct physical visual access to a person. So, for example, in the visual analysis, lines of low-height furniture or a window were not considered as barriers. On the other hand, in the physical accessibility analysis, lines of low-height furniture or a window were considered as barriers since they would hinder physical access, even though these objects were not necessarily obstructing visual access to a person. An example of an accessibility measure taken for a patient in 3203 is shown in Figure 5.13. After measuring accessibility for all patients in all the rooms, patients were categorized into five groups (patient groups 1,2,3,4, and 5) to understand which rooms provide the highest or the least accessibility to a patient with a unit (patient group 1 being highly accessible and the patient group 5 being the least accessible) (See Figure 5.14). Later, in statistical analyses, such group categorizations were converted to dummy group variables and tested to see how each group associates differently with inpatient falls. In other words, we tested, using this categorization, whether or not patients who were the least accessible (patient group 5) were associated with the increased risk of falling when compared to patients who were most highly accessible (patient group 1).

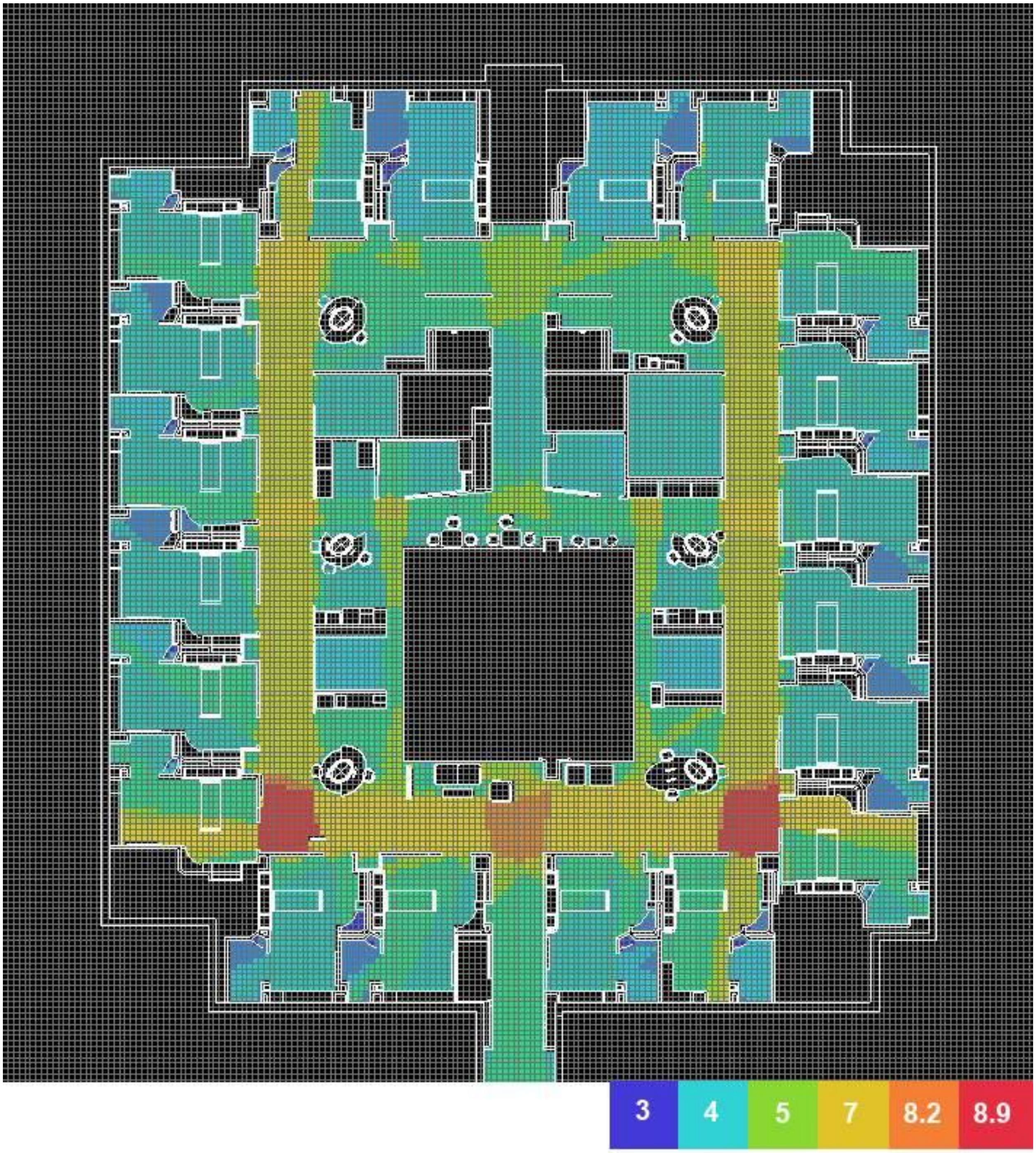


Figure 5.12: Analysis of Integration (Accessibility) by Depthmap (Unit 3200)

Figure 5.13: Measure of Integration (Accessibility) of the Patient (Body) in 3203 by Depthmap

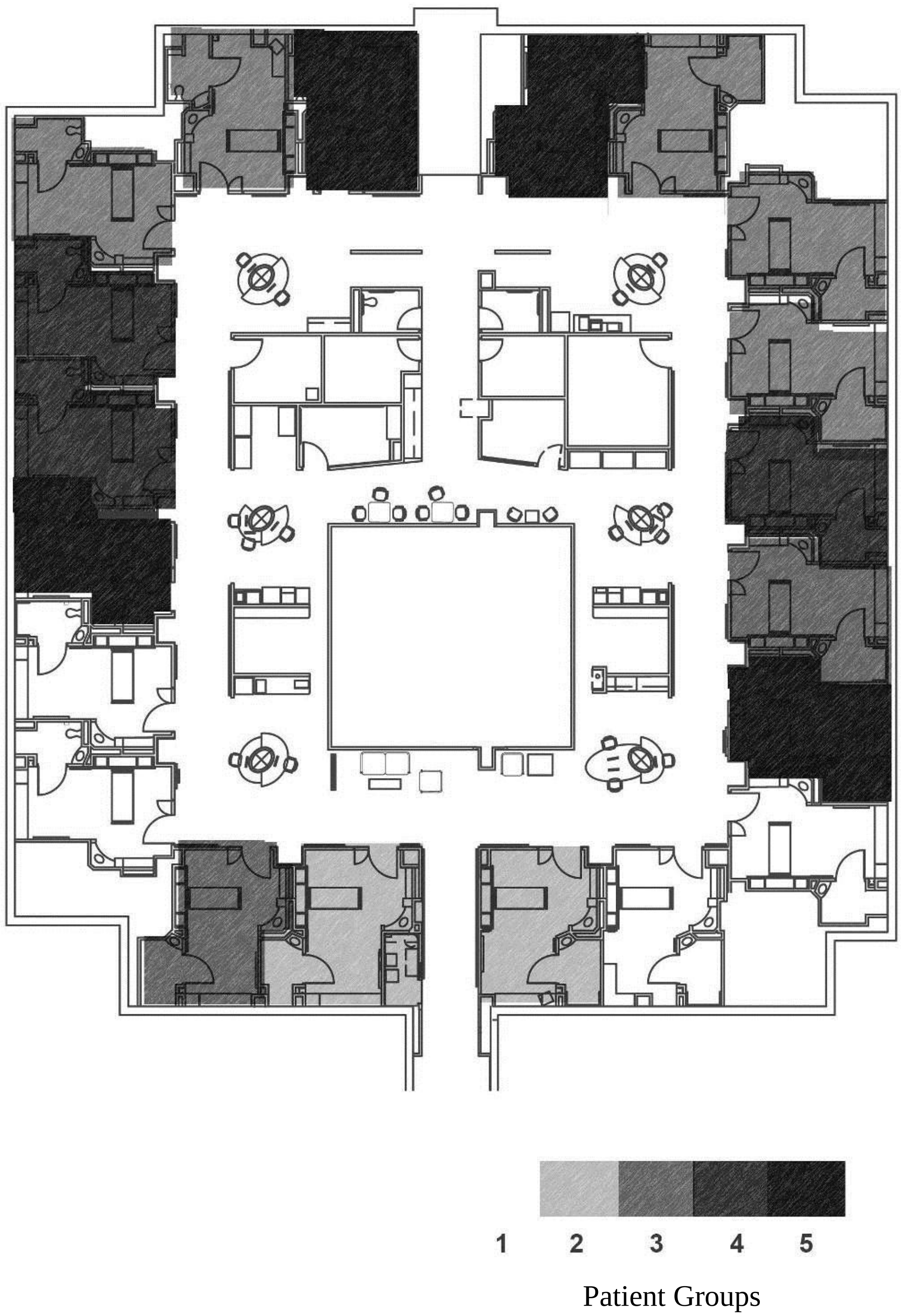


Figure 5.14 Five Patient Groups in Accessibility Measures (ranging from patient group 1 being most highly accessible to patient group 5 being the least accessible)

5.9.3 Distance to Medication Area

5.9.3.1 Definition and Process

The distance from the center of the medication dispensing machine to the center of the area in which a patient's head resides was measured by drawing a path between these two points using Autodesk AutoCAD 2011, to find the shortest distance possible (See Figure 5.15).

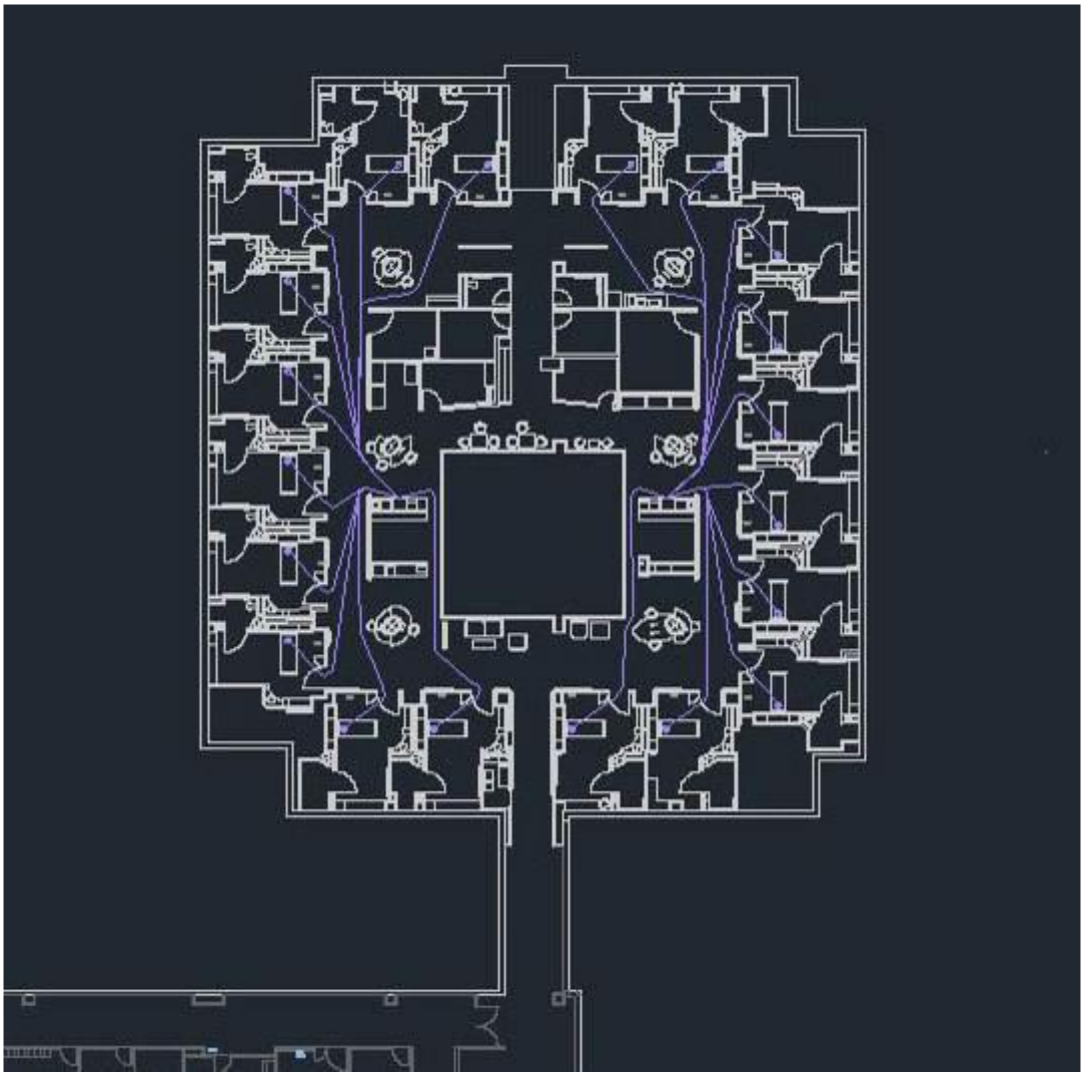
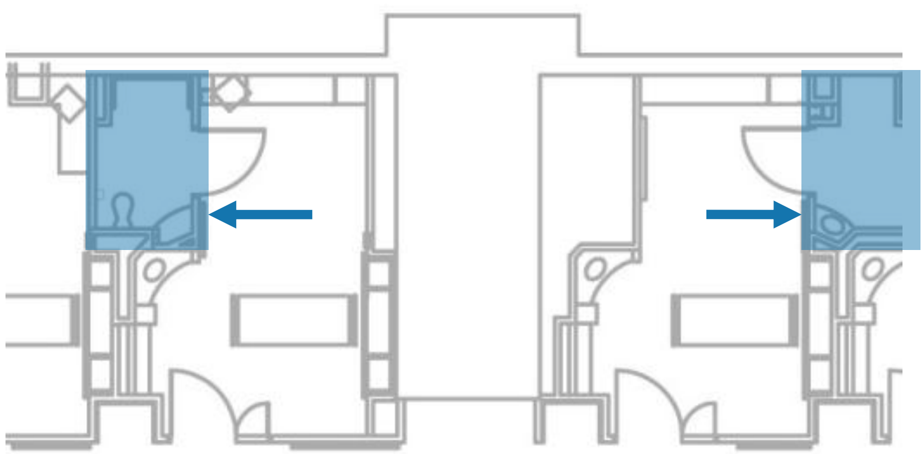


Figure 5.15 Paths to Medication Area in 3203 by AutoCAD Program

5.9.4 Bathroom Location in Relation to Patient

5.9.4.1 Definition and Process

Even though all patient rooms were nearly identical, there were a few exceptions. The patient bathroom in 12 out of 60 medical surgical inpatient rooms was located on the footwall side of the room. In the remaining 48 patient rooms, the bathroom was located at the headwall side. Therefore, patients were categorized differently depending on where his/her bathroom is located: 1) footwall side and 2) headwall side (Figure 5.16).



- Bathroom at the Footwall Side
- Bathroom at the Headwall Side

Figure 5.16 Bathroom Location in Relation to Patient

Table 5.2 Study Variables

Faller Data Collection		
Study Variable	**Measure**	**Data Source**
Patient Account Number	Numerical	Incident reporting forms
Report Date	e.g., 2/10/2011	Incident reporting forms
Incident Time	e.g., 2215	Incident reporting forms
Location (Unit Location)	e.g., 3200	Incident reporting forms
Patient Room Number	e.g., 3302	Patient medical records
Physical Location	e.g., Patient room, patient bathroom, or corridor	Incident reporting forms
Age	Numerical	Incident reporting forms
Gender	Male/Female	Incident reporting forms
Admitting diagnosis (description and number)	e.g., Back contusion (922.31)	Incident reporting forms
DRG	Numerical (e.g., 332)	Incident reporting forms
Length of stay at time of falling	Numerical (e.g., 5)	Patient medical records
Mobility (at time of falling)	Categorical (i.e., ambulates without problems, unable to ambulate, ambulates with assistive device, and ambulates unsteadily)	Incident reporting forms
mobility1	Group dummy variable: The mobility patient group1: Patients who ambulate without problems	Incident reporting forms
mobility2	Group dummy variable: The mobility patient group2: Patients who are unable to ambulate	Incident reporting forms
mobility3	Group dummy variable: The mobility patient group3: Patients who ambulate with assistive device	Incident reporting forms

mobility4	Group dummy variable: The mobility patient group4: Patients who ambulate unsteadily	Incident reporting forms
Mentation (at time of falling)	Categorical (i.e., alert, unresponsive, periodic confusion, and always confused always)	Incident reporting forms
mentation1	Group dummy variable: The mentation patient group1: Patients who are alert	Incident reporting forms
mentation2	Group dummy variable: The mentation patient group2: Patients who are unresponsive	Incident reporting forms
mentation3	Group dummy variable: The mentation patient group3: Patients who have periodic confusion	Incident reporting forms
mentation4	Group dummy variable: The mentation patient group4: Patients who are always confused	Incident reporting forms
Elimination (at time of falling)	Categorical (i.e., independent, independent with frequency, needs assistance, and incontinent)	Incident reporting forms
elimination1	Group dummy variable: The elimination patient group1: Patients who are independent	Incident reporting forms
elimination2	Group dummy variable: The elimination patient group2: Patients who are independent with frequency	Incident reporting forms
elimination3	Group dummy variable: The elimination patient group3: Patients who need assistance	Incident reporting forms

elimination4	Group dummy variable: The elimination patient group4: Patients who are incontinent	Incident reporting forms
Prior fall history (at time of falling)	Categorical (i.e., none, unknown, yes before admission)	Incident reporting forms
prior fall hx1	Group dummy variable: The prior_fall_hx patient group1: Patients with no history	Incident reporting forms
prior fall hx2	Group dummy variable: The prior_fall_hx patient group2: Patients with unknown history	Incident reporting forms
prior fall hx3	Group dummy variable: The prior_fall_hx patient group3: Patients with history of a fall before admission	Incident reporting forms
Current fall-related medication (at time of falling)	Categorical (i.e., none, anti-convulsants, tranquilizers, psychotropics, or hypnotics)	Incident reporting forms
meds1	Group dummy variable: The medication patient group1: Patients with no fall-related medications	Incident reporting forms
meds2	Group dummy variable: The medication patient group2: Patients receiving anti-convulsants	Incident reporting forms
meds3	Group dummy variable: The medication patient group3: Patients receiving tranquilizers	Incident reporting forms
meds4	Group dummy variable: The medication patient group4: Patients receiving psychotropics	Incident reporting forms

meds5	Group dummy variable: The medication patient group5: Patients receiving hypnotics	Incident reporting forms
Total Fall Risk Score (at time of falling)	Numerical (Total score weighed from five fall-related characteristics above)	Incident reporting forms

Non-Faller Data Collection		
Study Variable	**Measure**	**Data Source**
Patient Account Number	Numerical	Patient medical records
Location (Unit Location)	e.g., 3200	Patient medical records
Patient Room Number	e.g., 3303	Patient medical records
Age	Numerical	Patient medical records
Gender	Male/Female	Patient medical records
Admitting diagnosis	Number and description	Patient medical records
DRG	Number and description	Patient medical records
Admission/Discharge dates		Patient medical records
Length of stay, in which following six fall-related patient data is collected	Numerical	Patient medical records
Mobility	Categorical (i.e., ambulates without problems, unable to ambulate, ambulates with assistive device, or ambulates unsteady)	Patient medical records (Fall risk screen)
Same group dummy variables of the mobility patient groups as fallers		
Mentation	Categorical (i.e., alert, unresponsive, periodic confusion, and always confused)	Patient medical records (Fall risk screen)
Same group dummy variables of the mentation patient groups as fallers		

Elimination	Categorical (i.e., independent, independent with frequency, needs assistance, and incontinent)	Patient medical records (Fall risk screen)
Same group dummy variables of the elimination patient groups as fallers		
Prior fall history	Categorical (i.e., none, unknown, yes before admission)	Patient medical records (Fall risk screen)
Same group dummy variables of the prior fall history patient groups as fallers		
Current fall-related medication	Categorical (i.e., none, anti-convulsants, tranquilizers, psychotropics, and hypnotics)	Patient medical records (Fall risk screen)
Same group dummy variables of the medication patient groups as fallers		
Total Fall Risk Score	Numerical (Total score weighed from five fall-related characteristics above)	Patient medical records (Fall risk screen)

Physical Environment Assessment

Study Variable	Explanation	Measure
Visibility to patient		
Visibility I		
Visibility1_head area	The relative measure of the area that PT (HEAD area) is visible within 40 feet visual limit	Numeric
Visibility1body area	The relative measure of the area that PT (any parts of the BODY) is visible within 40 feet visual limit	Numeric

Visibility1_bc	Visibility1body is categorized into four groups. The lowest category is the best case (patients with the highest visibility)	Categorical
visibility1_bc_1	Dummy variable of the category 1, generated from Visibility1_bc	Patient group 1: patients who are the most visible
visibility1_bc_2	Dummy variable of the category 2, generated from Visibility1_bc	Patient group 2: patients who are less visible than group 1
visibility1_bc_3	Dummy variable of the category 3, generated from Visibility1_bc	Patient group 3: patients who are less visible than group 1 and 2
visibility1_bc_4	Dummy variable of the category 4, generated from Visibility1_bc	Patient group 4: patients who are the least accessible
Visibility II		
Visibility2_station	FROM AROUND A NEARBY NURSES' STATION AND A CORRIDOR PT heads and other part of bodies are visible around nurses' station Assumptions: 360 degree visual angle from any points within the boundary of nurses' stations	Categorical 1 = Visible from a nearby decentralized nurses' station and a corridor 2 = Visible only from a corridor (there are no cases in the category 3 that PTs are not visible at all from outside. Therefore, the category 3 is not included as an option).

Visibility2_h360	FROM DESIGNATED SEATS IN A NEARBY NURSES' STATION AND CORRIDOR PT **heads** are visible from **designated seats in their normal positions** in nurses' stations, allowing for **360 degree** visual angles from the seats.	Categorical 1 = Visible from **designated seats** in the close nurses' station and a corridor 2 = Visible only from corridor 3 = Not visible at all from outside (both a nearby decentralized nurses' station and a corridor)
Vis2_new_h360_1	Dummy variable of Visibility2_h360 (patient group 1): patients visible from designated seats in a nearby nurses' station and a corridor	
Vis2_new_h360_2	Dummy variable of Visibility2_h360 (patient group 2): patients visible only from corridor	
Vis2_new_h360_3	Dummy variable of Visibility2_h360 (patient group 3): patients not visible at all from outside (both a nearby decentralized nurses' station and a corridor)	

Visibility2_a360	FROM DESIGNATED SEATS IN A NEARBY NURSES' STATION AND A CORRIDOR PT **any parts of body** are visible from **designated seats** in nurses' stations, accounting for **360 degree** visual angles from them.	Categorical 1 = Visible from designated seats in a nearby decentralized and a corridor 2 = Visible only from corridor (there are no cases in category 3 that PTs are not visible at all from outside in the measure. Therefore, the category 3 is not included as an option).
Visibility2_h210	FROM DESIGNATED SEATS IN A NEARBY NURSES' STATION AND A CORRIDOR PT **heads** are visible from **designated seats** in nurses' stations, considering exact seat locations and their orientations in use and **210 degree** visual angles from them.	Categorical 1 = Visible from **designated seats** in a nearby decentralized nurses' station and a corridor 2 = Visible only from corridor 3 = Not visible at all from outside (both a nearby decentralized nurses' station and a corridor)
vis2_new_h210_1	Dummy variable of the category 1, generated from Visibility3_h210	Patient group 1: patients who are visible from a nearby decentralized nurses' station
vis2_new_h210_2	Dummy variable of the category 2, generated from Visibility3_h210	Patient group 2: patients who are visible only from corridor
vis2_new_h210_3	Dummy variable of the category 3, generated from	Patient group 3: patients who are not visible at all

	Visibility3_h210	from outside of PT room.
Visibility2_a210	FROM DESIGNATED SEATS IN A NEARBY NURSES' STATION AND A CORRIDOR	Categorical 1 = Visible from a nearby decentralized nurses' station or/and other functional spaces
	PT **any parts of body** are visible from **designated seats** in nurses' stations, considering exact seat locations and their orientations in use, and **210 degree visual angles** from them.	2 = Visible only from only corridor (there are no have cases in category 3 that PTs are not visible at all from outside in the measure. Therefore, the category is not included as an option).
visibility2_a210_1	Dummy variable of the category 1, generated from Visibility3_a210	Patient group 1: patients who are visible from a nearby decentralized nurses' station and a corridor
visibility2_a210_2	Dummy variable of the category 2, generated from Visibility3_a210	Patient group 2: patients who are visible only from corridor
Accessibility to patient		
Accessibility_body	The relative measure the determines accessibility to PT's body in each room (The higher the measure, the less accessible the PT is)	Numeric
Access_cb_5	Accessibility measures above(body) are categorized into 5 groups	Categorical
Access_cb_5_new_1	Dummy variable of category 1, generated from Access_cb_5_new	Patient group 1: patients who are most highly accessible within unit

Access_cb_5_new_2	Dummy variable of category 2, generated from Access_cb_5_new	Patient group 2: patients who are less accessible than group 1
Access_cb_5_new_3	Dummy variable of category 3, generated from Access_cb_5_new	Patient group 3: patients who are less accessible than groups 1 and 2
Access_cb_5_new_4	Dummy variable of category 4, generated from Access_cb_5_new	Patient group 4: patients who are less accessible than groups 1, 2, and 3
Access_cb_5_new_5	Dummy variable of category 5, generated from Access_cb_5_new	Patient group 5: patients who are the least accessible
Distance to MED (Pyxis machine)	Distance from patient head to the center of the medication area has been measured	Numeric (inches)
Bathroom Location		Categorical 1 = Located in the FOOTWALL side 2 = Located in the HEADWALL side

5.10 Data Analysis

5.10.1 Data Analysis: Overview

Several different data analysis techniques were used to maximize the understanding of the relationship between physical environmental factors and patient falls. First, a **descriptive analysis of patient falls** was performed to understand the characteristics and circumstances of patient falls. Second, a **visual representation of patient falls** was performed to understand spatial patterns of patient falls and fall-related patient characteristics. This was done by mapping the data onto floor plans. Third, **Pearson Correlation and Chi-square Tests** were performed as intermediate analyses to identify significant differences in environmental and other study variables between the two patient groups. Finally, **multivariate Logistic Regression Analyses** were performed to identify fall risk factors, especially environmental risk factors using the patient as unit of analysis. These multivariate logistic regression analyses were performed in four steps: **1) a whole-group analysis** with all patient samples (88 patient falls and 148 comparable non-fallers); **2) a sub-group analysis** with only the 78 unassisted patients who experienced falls and their 131 comparable non-fallers); **3) additional analyses** to address a concern for multi-collinearity; and **4) the final analysis** incorporating lessons-learned from the previous three steps and, therefore, excluding highly correlated variables. This section will report findings from all the different analyses, including the series of sub-analyses of the Multivariate Logistic Regression Analyses.

5.10.2 Descriptive Analyses of Patient Falls

Descriptive analyses of patient falls were conducted to maximize the understanding of patient falls themselves and their spatial patterns to identify factors contributing to the patterns. From the falls incident reports, additional information was available regarding the 88 fall incidents: 1) incident (or event) type: whether or not a patient fell from bed, chair, bedside commode; fell while standing/ambulating, or fell while in shower/tub or bathroom; 2) Time of day: when a fall occurred 3) Discovery type: whether or not a fall was witnessed, self-reported, or a faller was found on the floor after the incident), and 4) Assist type: whether or not a fall occurred while a patient was being assisted. This information has been analyzed to explore the circumstances of inpatient falls included in this study and it is presented in the results section 6.1 (See Table 6.1).

In addition to this, significant fall-related patient characteristics (i.e., age, gender, LOS at time of falling, mobility, mentation, elimination, prior fall history, current fall-related medication, and total fall risk score) included in the main analyses were also analyzed separately to maximize the understanding of fallers' intrinsic characteristics and compared to non-fallers (See Table 6.4).

5.10.3 Visual Representation of Patient Falls and Fall-related Patient Characteristics

Using the overall patient data that includes all patients admitted to the hospital during the study period (Jan. 08, 2008 – Jan. 7, 2011), the following data was calculated on a per-room basis: 1) the number of patients admitted to each room, 2) the number of patient-days per patient admitted to each room, 3) the total patient-days per room, 4) the average age of patients admitted to each room, and 5) the percentage of patients who were 60 or older in each room. Combining the information with the fall incident data (e.g., a number of falls per room), fall rate per 1,000 patient days (a standard in the field) per room was calculated as well as the percentage of patients who were 60 or older.

5.10.4 Intermediate Analyses: Pearson Correlation and Chi-square Tests

Intermediate analyses (i.e., Pearson correlation and chi-square tests) were performed to reveal any significant differences in the variables of interest between the case and the control groups. Although these comparative analyses do not provide the ability to control for other factors under discussion, they still can discern any significant differences in variables that may need further attention in subsequent analyses.

5.10.5 Multivariate Logistic Regression Analyses

Data were entered into IBM SPSS statistical computer program version 19 for analysis. The magnitude of the associations between potential risk factors and falling was quantified with the use of the odds ratios, which were later translated into the probability of falling. Logistic regression models were used to analyze binary dependent variables (a fall is sustained or not). In logistic regression, the dependent variable is binary or dichotomous. The goal of logistic regression is to find the best fitting (yet reasonable) model to describe the relationship between the dichotomous characteristic of interest (dependent variable) and a set of independent (predictor or explanatory) variables. Logistic regression calculates adjusted odds ratios (aORs)—approximations of the relative risk—with 95% confidence intervals (CIs) for the presence of the characteristic of interest. These multivariate logistic regression analyses compared environmental factors (e.g., visibility, accessibility, and distance to medication) measured from fallers' locations in their rooms to non-fallers' locations in their patient rooms and determined which factors significantly increased the relative risk of falling. From this, multivariate models were constructed with two sets of variables (fall-related patient variables and environmental variables) to control for the possible effect of the fall-related patient characteristics on patient falls when testing the effect of environmental variables. A representative logistic regression equation can be as follows:

logit(p) = b + b1*(age) + b2*(gender) + b3*(length of stay at time of falling) + b4* (mobility) + b5*(mentation) + b6*(elimination) + b7*(history of falls) + b8*(current fall-related medication) + b9*(fall risk score) + b10*(Visibility I) + b11*(Visibility II) + b12*(accessibility) + b13*(distance to medication) + b14*(bathroom location in related to patient)

5.10.6 Multivariate Logistic Regression Analyses: The Process

Multivariate Logistic Regression Analyses were performed through several steps.

Step 1 consisted of whole-group analyses examining data from 88 patient falls and 148 comparable non-fallers.

Step 2 was sub-group analyses of 78 unassisted patients who experienced falls and 139 comparable non-fallers. In identifying the most effective multivariate logistic regression model, we ran the model with a sub-group of 78 unassisted falls and 131 comparable non-fallers because the sub-group appears to be a good fit to a fundamental assumption of the study, linking environmental factors to organizational function through their impact on surveillance, awareness, and timeliness. Ten falls that occurred while staff was assisting will not adequately represent the impact of the physical environment on surveillance, awareness, and timeliness. Therefore, those ten assisted falls were excluded, and the model was tested to see if there were any differences in the relationship between environment factors of interest and the outcome (i.e., patient falls).

Step 3 included additional analyses to address concerns with multi-collinearity in the main multivariate logistic regression analyses based on Steps 1 and 2. One of the strengths of the study is its ability to investigate the impact of various fall-related patient characteristics on inpatient falls and to control for them during analyses, so that the significant associations between certain physical environmental factors and inpatient falls can be solely attributable to those environmental factors. Such an approach strengthens the study, but it also creates a concern about multi-collinearity or multiple co-dependences among various variables, which might bias the outcome. Therefore, the current study conducted additional analyses that attempted to minimize concerns about multi-collinearity and its impact on the main statistical outcomes present in Section 6.3 (Physical Environmental Risk Factors Increasing the Probability of Experiencing a Fall: A Case-Control Study of Inpatient Falls). Results of these additional analyses are presented in Appendix B.

Step 4 was the final analysis incorporating lessons-learned from the previous three steps. The final model with a limited number of collinear variables was developed by dropping three of highly correlated variables (age, fall risk score, and Visibility I) and only included variables that contribute considerably to the joint predictive ability of variables in the model.

5.10.7 The Advantage of Multivariate Logistic Regression Models

The greatest advantage of multivariate analysis is that the model takes into account impacts of other factors in the model when testing one factor by one factor within the model, and, therefore, the outcome of the analysis more closely represents the phenomena of interested. Presumably, each patient is associated with several different environmental factors, which play their own role and, therefore, each factor must be tested while taking into account the effects of other factors. For example, among patients with similar visibility, some patients may have a greater risk of falling if they are less accessible. If the impact of visibility was not properly controlled, it might not have been possible to properly identify the impact of accessibility on the outcome of interest. There are14 different variables in the model, which means that the outcome of each variable is evident when the analysis has controlled impacts of all the remaining variables in the model.

5.10.8 Multivariate Logistic Regression: Unit of Analysis

In the study, the patient was the unit of analysis, and each patient was bound to a certain binary outcome, "suffered a fall or not," during their hospital stays. For patients who sustained multiple recorded falls during their stays, the investigator included only the first fall in the analysis, reflecting the use of the patient as the unit of analysis. The investigator might instead have considered the patient room as the unit of analysis but several potential limitations can be associated with the approach. First, using that approach, the sample size decreases to 60 from 236 samples since there were only 60 patient rooms among the three inpatient units. However, when the patient is the unit of analysis, the sample could be up to 236 samples. Second, the sensitivity of the outcome variable would be limited if the room was the unit of analysis. Since patient falls are such rare events, the number or the rate per room does not show much variance. Finally, there are additional difficulties controlling for other fall-related patient characteristics if the room was used as the unit of analysis. It was manageable to identify each patient's fall-related characteristics and to control for them when the patient was considered as the unit of analysis. But when it comes to the room, the control of those additional factors can be challenging since the investigator might need complete access to patient data to estimate the factors per room. Therefore, because of these limitations, the patient was chosen as unit of analysis.

To estimate the effects of certain environmental variables upon the probability of a fall, it was necessary to identify a control group of non-fallers. Therefore, the study followed a case-control study design, identifying a group of patients who had a profile as similar as possible to patients who fell, but who did not fall.   For the case-control study design, having a nearly-identical individual match is less important than having the overall characteristics of the control group match the overall characteristics of the group who fell. The control group needed to be between 100% and 300% the size of the fall group. In addition, by identifying the control group of patients who did not suffer falls but who fit a similar intrinsic profile as fallers, the study aimed at controlling for the influence of certain intrinsic patient characteristics (i.e., age, gender, admitting diagnosis, and DRG) on patient falls, which may have the potential to mask the association between design factors and patient falls.

5.10.9 Six Multivariate Logistic Regression Models

As mentioned earlier, the Visibility I and Visibility II measures are based on different assumptions or definitions of patient visibility. With different combinations of the sub-measures of these two measures, there were five different multivariate logistic regression models, shown below (Table 5.3). Table 5.3 only shows the six different combinations of environmental factors entered into multivariate logistic regression models. As mentioned earlier in the Section 5.9.3, the representative logistic regression equation is as follows:

logit(p) = b + b1*(age) + b2*(gender) + b3*(length of stay at time of falling) + b4* (mobility) + b5*(mentation) + b6*(elimination) + b7*(history of falls) + b8*(current fall-related medication) + b9*(fall risk score) + b10*(**Visibility I**) + b11*(**Visibility II**) + b12*(**accessibility**) + b13*(**distance to medication**) + b14*(**bathroom location in related to patient**)

Keeping nine patient-related variables the same, six different multivariate logistic regression models were created with a different combination of the environmental factors (See table 5.3). Intentionally sub-measures measured from patients' heads were not mixed with sub-measures measured from patient's body when constructing the models. Within the same model, numerical variables like Visibility I or accessibility were tested as several forms (i.e., numerical, categorical, and group or dummy variables). In other words, numerical variables like Visibility I and accessibility were also categorized into 3 or 5 groups and tested as group (i.e., dummy) variables as well. Categorical variables like Visibility II were also tested as both categorical and group dummy variables. Therefore, within each of the six multivariate models, there were several different sub-models, depending on whether or not the variables were numerical, categorical, or group variables.

The purpose of creating these additional sub-models (or testing different forms of variables) was to precisely identify the direction or trend of the association between each variable and the outcome. For example, even though we did not identify the numerical measure of visibility to be significant, it is possible that some groups of group dummy variables of the variable may be significantly associated with the outcome. In fact, we have seen such case during analyses of this study. The patient variable 'mentation' did not turn out to be significant as a categorical variable but one of group dummy variables was significantly associated with the outcome. For this case, one group of patients associated with the mentation variable "periodic confusion" had a significantly higher probability of falling when compared to the other group, patients with alert mentation. Therefore, even though Table 5.3 only shows six representative models, approximately 24 different models were actually tested to identify specific groups of variables significantly associated with inpatient falls.

During the analyses, group (dummy) variable forms of variables were always preferred over numerical and categorical forms of variables and, therefore, tested first. Then, the forms of each variable were changed to identify best-fitting models.

Table 5.3 Six Different Combinations of Environmental Factors Entered into Multivariate Logistic Regression Models

	Visibility I	Visibility II	Accessibility	Distance to medication	Bathroom location
Model 1	Visibility1_ headarea	Visibility2_ _station	Accessibility_ body	Dist_med	Bathroom_ location
Model 2	Same as above	Visibility2_ head_seats_ 360	Same as above	Same as above	Same as above
Model 3	Same as above	Visibility2_ head_seats_ 210	Same as above	Same as above	Same as above
Model 4	Visibillty2_ body	Visibility2_ station	Same as above	Same as above	Same as above
Model 5	Same as above	Visibility2_ body_seats_ 360	Same as above	Same as above	Same as above
Model 6	Same as above	Visibility2_ body_seats_ 210	Same as above	Same as above	Same as above

5.10.10 Six Multivariate Logistic Regression Models: Equations

A precise multivariate logistic regression equation per each model is presented below.

Model 1

logit(p) = b + b1*(age) + b2*(gender) + b3*(length of stay at time of falling) + b4* (mobility) + b5*(mentation) + b6*(elimination) + b7*(history of falls) + b8*(current fall-related medication) + b9*(fall risk score) + b10*(**visibility1_headarea**) + b11*(**visibility2_station**) + b12*(**accessibility_body**) + b13*(**distance to medication**) + b14*(**bathroom location in related to patient**)

Model 2

logit(p) = b + b1*(age) + b2*(gender) + b3*(length of stay at time of falling) + b4* (mobility) + b5*(mentation) + b6*(elimination) + b7*(history of falls) + b8*(current fall-related medication) + b9*(fall risk score) + b10*(**Visibility1_headarea**) + b11*(**Visibility2_head_seats_360**) + b12*(**accessibility_body**) + b13*(**distance to medication**) + b14*(**bathroom location in related to patient**)

Model 3

logit(p) = b + b1*(age) + b2*(gender) + b3*(length of stay at time of falling) + b4* (mobility) + b5*(mentation) + b6*(elimination) + b7*(history of falls) + b8*(current fall-related medication) + b9*(fall risk score) + b10*(**Visibility1_headarea**) + b11*(**Visibility2_head_seats_210**) +

b12*(**accessibility_body**) + b13*(**distance to medication**) + b14*(**bathroom location in related to patient**)

Model 4

logit(p) = b + b1*(age) + b2*(gender) + b3*(length of stay at time of falling) + b4* (mobility) + b5*(mentation) + b6*(elimination) + b7*(history of falls) + b8*(current fall-related medication) + b9*(fall risk score) + b10*(**Visibility1_bodyarea**) + b11*(**Visibility2_station**) + b12*(**accessibility_body**) + b13*(**distance to medication**) + b14*(**bathroom location in related to patient**)

Model 5

logit(p) = b + b1*(age) + b2*(gender) + b3*(length of stay at time of falling) + b4* (mobility) + b5*(mentation) + b6*(elimination) + b7*(history of falls) + b8*(current fall-related medication) + b9*(fall risk score) + b10*(**Visibility1_bodyarea**) + b11*(**Visibility2_anypartbody_seats_360**) + b12*(**accessibility_body**) + b13*(**distance to medication**) + b14*(**bathroom location in related to patient**)

Model 6

logit(p) = b + b1*(age) + b2*(gender) + b3*(length of stay at time of falling) + b4* (mobility) + b5*(mentation) + b6*(elimination) + b7*(history of falls) + b8*(current fall-related medication) + b9*(fall risk score) + b10*(**Visibility1_bodyarea**) + b11*(**Visibility2_anypartbody_seats_210**) + b12*(**accessibility_body**) + b13*(**distance to medication**) + b14*(**bathroom location in related to patient**)

CHAPTER 6

RESEARCH RESULTS

6.1 Description of Inpatient Falls

A total of 94 inpatient falls were reported from the five inpatient units at DMH between January 08, 2008 and January 07, 2011. The study included only inpatient falls, excluding any falls by visitors, staff, and outpatients. The 94 inpatient falls occurred among 92 patients, 2 of whom fell twice and 4 of whom were patients of Labor/Delivery and Mother/Baby units. All 94 patient falls occurred in patient rooms. To better control the impact of patient characteristics on the outcome of interest, the current study excluded both the two second-time falls sustained by the medical-surgical patients and the four falls sustained by patients in the Labor/Delivery and Mother/Baby units. Therefore, the current study includes 88 inpatient falls sustained by medical-surgical patients admitted to the three medical-surgical units at DMH. Based on the total of 36,783 patient-days () for the three medical-surgical units, the fall rate of the units corresponds to 2.4 falls per 1,000 patient-days.

The average age of patients who fell was 65.6 years (range 22 to 95). Many falls occurred when patients did not have staff present to assist them 87.5% and the falls were not witnessed (i.e., patients were found on floor or the fall was self-reported) (68%), they tended to occur during the daytime (59%), and often occurred while the patient was standing or ambulating (49%) (See Tables 6.1 and 6.2).

Table 6.1 Circumstance of First Falls (N = 88)

Descriptors	**Falls *N =88* (%)**
Fall Type	
Fell from bed	18
Fell from chair	15
Fell from bedside commode	8
Fell while standing/ambulating	43
Fell in the shower/tub	1
Fell while in bathroom	1
Unknown	2
Time of day	
7:00AM – 6:59PM	50
7:00 PM – 6:59AM	38
Discovery Type	
Found on floor/self-reported	60
Witnessed	28
Assist type	
Unassisted	78
Assisted by employee	9
Unknown	1

Table 6.2 Patient Characteristics: Falls (N =88) and Controls (N= 148)

Factor	**Falls *N =88* (%)**	**Controls *N =148* (%)**
Age (mean)	65.61	65.77
Gender(M/F)	41/47	56/92
LOS at time of falling (mean)	4.05	3.18
Mobility		
Ambulate without problems	18 (20.5)	46 (31.1)
Unable to ambulate	4 (4.5)	11 (7.4)
Ambulate with assistive device	31 (35.2)	47 (31.8)
Ambulate unsteady	35 (39.8)	44 (29.7)
Mentation		
Alert	59 (67.1)	126 (85.1)
Unresponsive	0 (0)	1 (.7)
Periodic confusion	25 (28.4)	15 (10.1)
Confusion always	4 (4.5)	6 (4.1)
Elimination		
Independent	20 (22.7)	41 (27.7)
Independent with frequency	6 (6.8)	5 (3.4)
Needs assistance	54 (61.4)	92 (62.2)
Incontinent	8 (9.1)	10 (6.8)
Prior fall history		
No	45 (51.1)	85 (57.0)
Unknown	23 (26.1)	25 (16.8)
Yes before admission	19 (21.6)	38 (25.5)
Current fall-related medication		
None	64 (72.7)	102 (68.4)
Anti-convulsant	1 (1.1)	1 (.6)
Tranquilizers	3 (3.4)	5 (3.4)
Psychotropics	11 (12.5)	14 (9.4)

Hypnotics	9 (10.23)	26 (17.5)
Fall risk score (mean)	.216	.264

6.2 Spatial Representation of Patient Falls and Relevant Patient Characteristics

6.2.1 Introduction

Before attempting any statistical analyses, the investigator sought to understand the spatial patterns of patient falls and relevant patient-related characteristics during the three years covered by the study, by mapping the data onto floor plans of the three inpatient units. It will be the basis of further investigation of environmental factors associated with inpatient falls in the next phases of the analyses.

The spatial patterns of inpatient falls cannot be fully understood simply by collecting data about patient rooms and the rates of falls in those rooms. The rate of falls can be affected by many factors other than environmental factors. This study selected two non-environmental variables, high volume rooms and patients who were over 60 years old. The assumptions were that rooms with a high patient "turnover" and rooms occupied more often by patients over 60 will have higher rates of inpatient falls. Unexpectedly, the analysis of room and fall data based on these non-environmental factors did not reveal a simple correlation with either high volume or over-60 room occupancy. The lack of relevancy of patient age was especially surprising, given that patient age has been shown to be a major factor in calculating fall risk, and advanced age contributes significantly to other fall-related factors such as level of mentation, mobility, and fall history.

6.2.2 Spatial Dashboard on Patient Falls, Based on a Fall Rate per Room

It is possible that some rooms may have more falls merely because the rooms have had more patients or more patient-days than other rooms. It is likely for inpatient units at DMH that some patient rooms have higher patient "turnover" than other rooms because of following reasons: 1) medical-surgical units at DMH have a relatively low patient census and are on average, 60% full over the course of year. The three medical surgical units reported that they recorded 36,783 patient-days in total during the past three years. These three inpatient units were fully occupied during just 56% (or 65,700) patient-days during the past three years. It was a rare case for the three medical-surgical units to have all the patient rooms fully occupied on any given day. Hospital staff also indicated that some rooms are routinely assigned to patients more often than others. Nurses reported anecdotally that they tended to admit patients to rooms near the entrance and near the medication room first because those busy areas have more people around. Then, as those rooms fill, they admit patients to rooms in the back of the units. Data gathered from this study confirmed that 1) patient-days per room ranged from 195 to 858 over the past three years and 2) rooms with the least patient-days were mostly located at the back side of the units (e.g., 3213, 3212, 3211, 3313, 3312, 3308, 4213, 4212, and 4214) (See Figure 6.5 and Table 6.3).

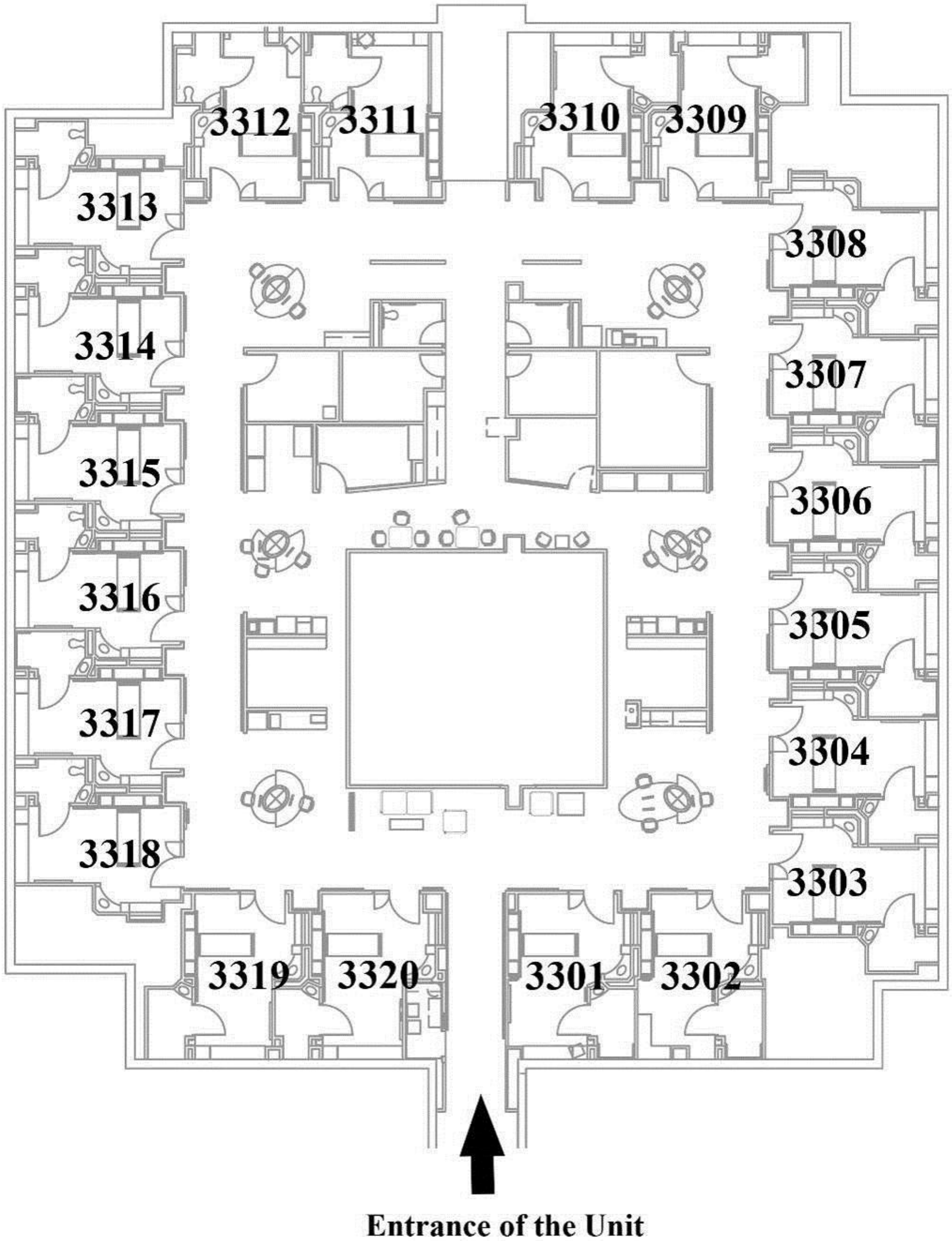


Figure 6.1: The Floor Plan of Unit 3200 with Room Numbers

Table 6.3 Patient-days per Room

Unit 3200		Unit 3300		Unit 4200	
Room number	Patient-days per room	Room number	Patient-days per room	Room number	Patient-days per room
3213	**440**	**3313**	**468**	**4213**	**148**
3212	**475**	**3312**	**546**	**4212**	**195**
3211	**600**	**3310**	**672**	**4214**	**298**
3201	633	3308	678	4211	352
3215	642	3311	693	4216	360
3208	643	3309	705	4215	375
3209	644	3314	755	4217	375
3214	653	3306	757	4220	401
3217	662	3320	760	4218	407
3210	670	3307	778	4209	441
3207	672	3319	785	4219	444
3216	673	3305	794	4210	451
3206	674	3317	796	4208	485
3202	688	3304	804	4207	526
3220	698	3318	818	4206	528
3204	702	3302	824	4202	547
3218	702	3315	836	4205	548
3219	715	3303	840	4203	567
3205	722	3301	857	4204	580
3203	739	3316	858	4201	684

Due to the significant differences in patient-days per room, it was necessary to control for their impact on the apparent number of patient falls per room so the data was measured in terms of a fall rate of 1,000 patient-days per room. This fall rate per room was represented through a spatial dashboard of patient falls (or patient fall rates) per room and visually illustrates where or in which patient rooms most falls occurred. The dashboard was particularly useful for identifying rooms with a high patient fall risk. The spatial dashboards of the three units (i.e., 3200, 3300, and 4200) on patient falls (or fall rates) are shown in Figures 6.2, 6.3, and 6.4 respectively.

The dashboard indicates the higher rate of falls in certain rooms, especially corner rooms located in the back side of the unit. It was especially interesting to observe such a prevalence of falls in those rooms because, in most cases, they housed the fewest number of patients, accounted for the least patient-days, and were the last for nurses to assign to patients, especially for high fall risk patients. In other words, if we consider some care process-related factors, those rooms might have been associated with the least risk of patient falls. This finding strongly suggests that spatial dashboard of patient falls can be an invaluable tool in identifying and analyzing factors that may be associated with patient falls or locations of patient falls.

Helping us potentially rule out the impact of some outstanding care process-related factors (e.g., patient-days per room), this spatial dashboard of patient falls can be a great point of discussion or observation to identify any other factors that may be associated with patient falls or locations of patient falls.

Figure 6.2: The Spatial Dashboard of Patient Falls: The Analysis of Fall Rate per Room (Unit 3200)

Figure 6.3: The Spatial Dashboard of Patient Falls: The Analysis of Fall Rate per Room (Unit 3300)

Figure 6.4: The Spatial Dashboard of Patient Falls: The Analysis of Fall Rate per Room (Unit 4200)

6.2.3 Spatial Dashboard on the Prevalence of Older Patients, Based on the Percentage of Patients 60 or older, per Room

One can also argue that some rooms are associated with a higher fall rate simply because, on average, they house older. The literature indicates that the increased patient age (60 or older) was one of the most significant predictors of patient falls (Halfon et al., 2011, Hitcho et al., 2004, Krauss et al., 2007, Oliver et al., 2004, Schwendimann et al., 2008). To understand whether or not a room with more days occupied by older patients (60 or over) is related to the outcome of the first spatial dashboard on patient falls, it was necessary to calculate the percentages of patient-days that each room housed patients 60 or older. The spatial dashboards of the three units (i.e., 3200, 3300, and 4200) on the prevalence of patient-days with older patients are shown in Figures 6.5, 6.6, and 6.7 respectively.

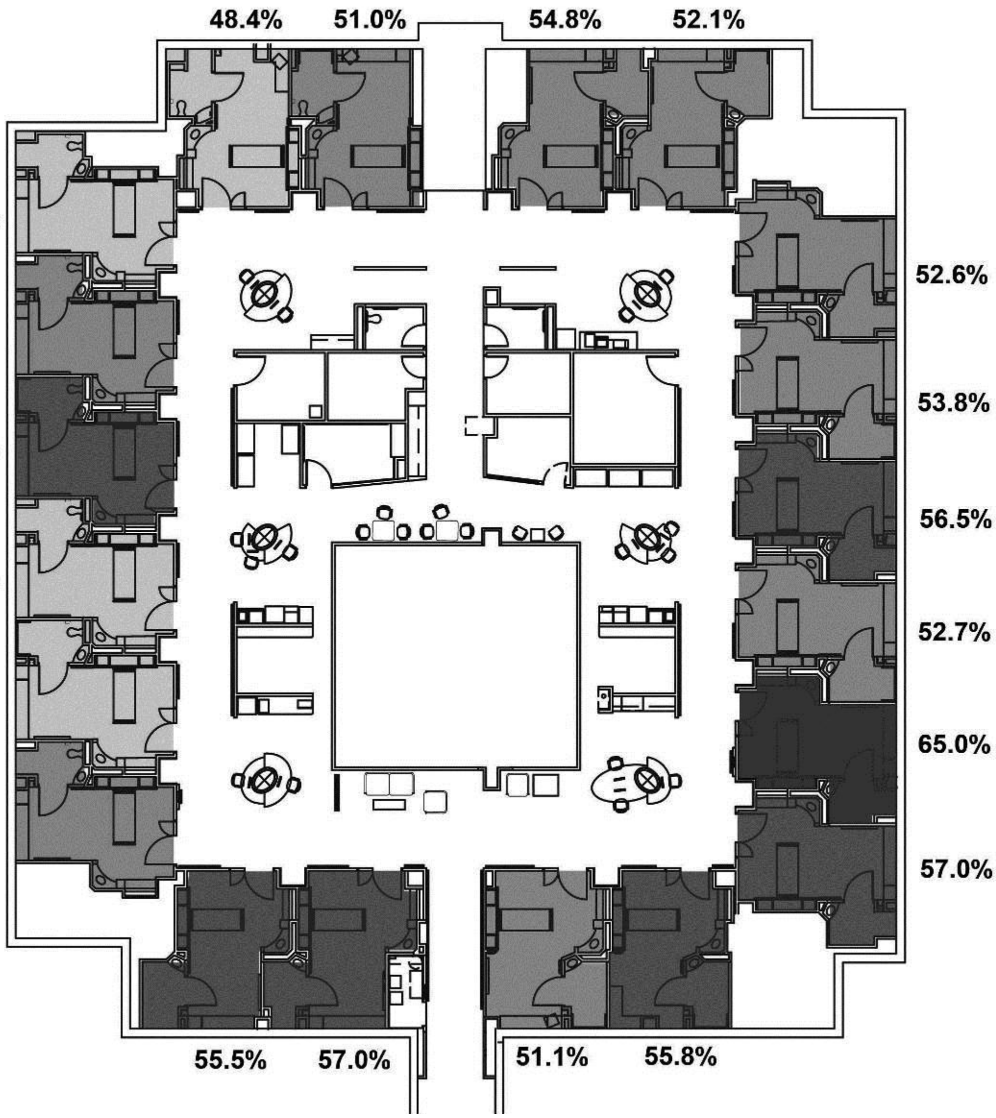


Figure 6.5: The Spatial Dashboard of the Prevalence of Patient-Days with Older Patients (60 or older): The Analysis of the Percentage of Patient-Days with Older Patients per Room (Unit 3200)

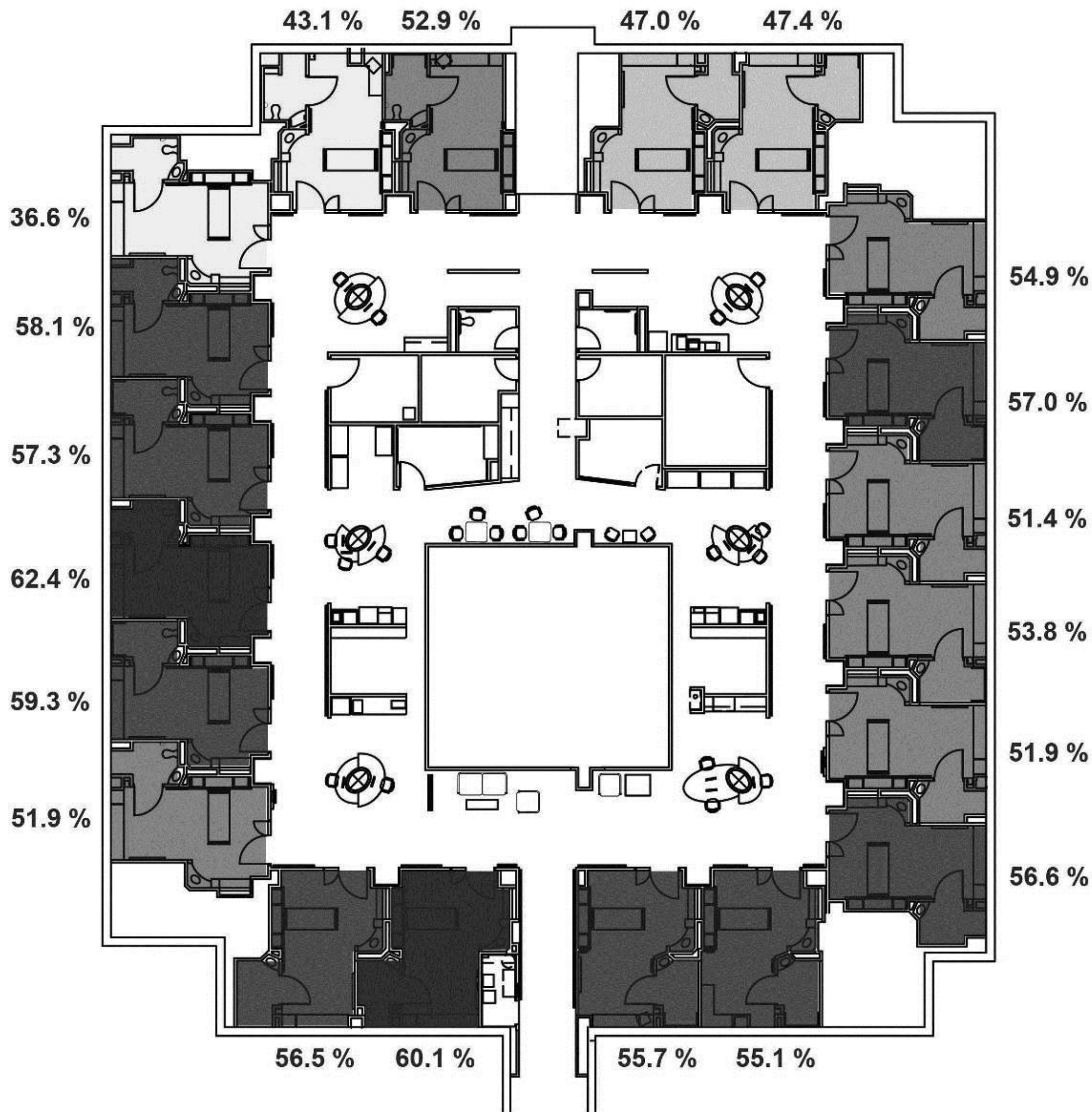


Figure 6.6: The Spatial Dashboard of the Prevalence of Patient-Days with Older Patients (60 or older): The Analysis of the Percentage of Patient-Days with Older Patients per Room (Unit 3300)

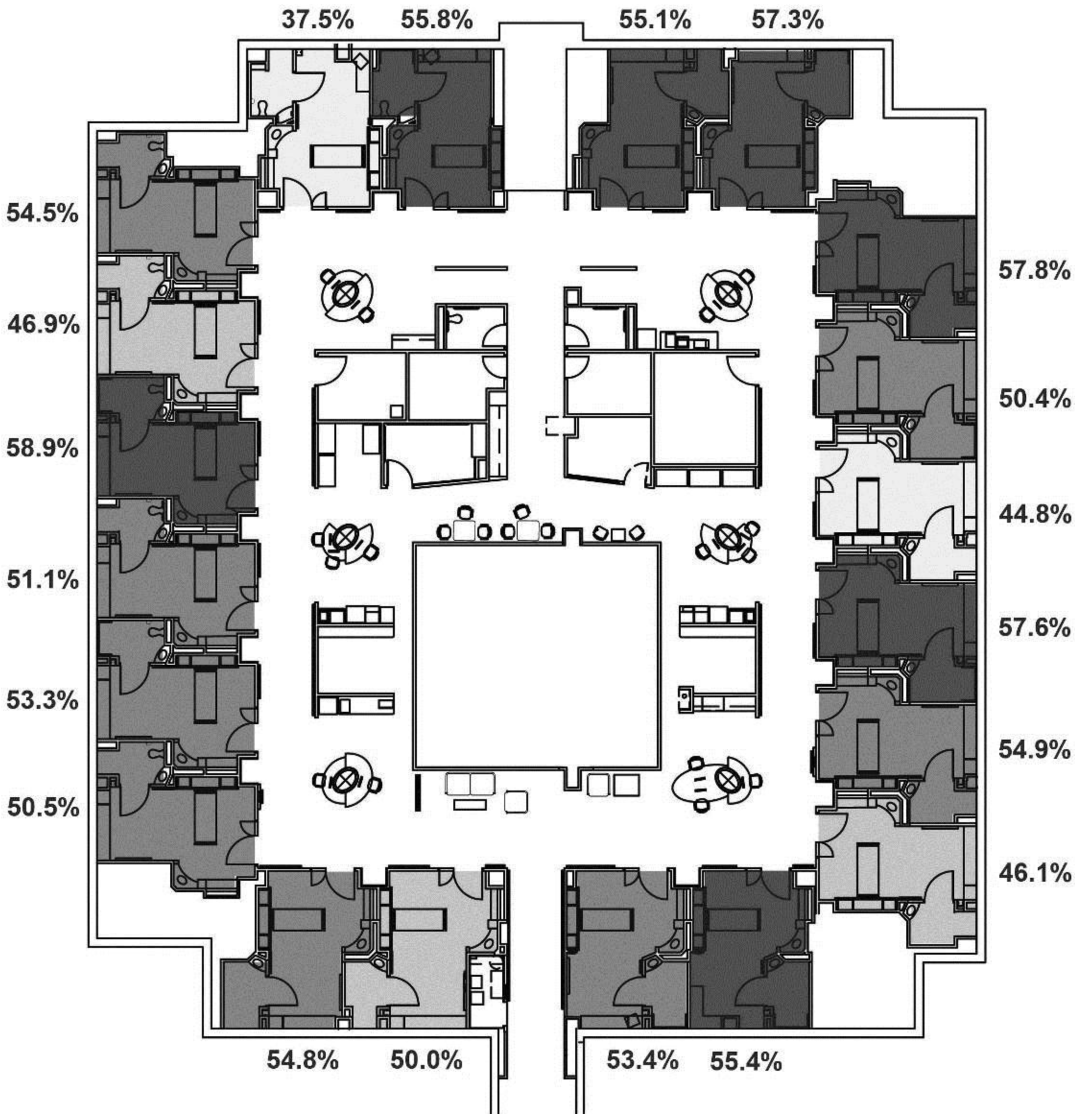


Figure 6.7: The Spatial Dashboard of the Prevalence of Patient-Days with Older Patients (60 or older): The Analysis of the Percentage of Patient-Days with Older Patients per Room (Unit 4200)

In addition, Figures 6.8, 6.9, and 6.10 compare two dashboards (one for patient fall rates and the other for the percentage of patient-days with older patients) per unit so in order to better understand the relationship between the percentage of patient-days with older patients and the fall rate per room. Figure 6.8 clearly shows a lack of correlation between the percentage of patient-days with older patients and a room's fall rate. In other words, certain patient characteristics for rooms (i.e., higher percentage of patient-days with older patients) apparently did not contribute to the spatial patterns of patient falls. For example, in Figure 6.8, the rooms with the highest fall rates (i.e., rooms 3208, 3209, 3212, and 3219) were, in fact, occupied on fewer days by older patients than other rooms with lower over-60 patient days (e.g., 3202, 3203, or 3204). This disassociation was evident for the other two units as well (See Figures 6.9 and 6.10).

Figure 6.8: The Comparison of Spatial Dashboards (Unit 3200): Patient Fall Rates versus the Percentage of Patient-Days with Older Patients (60 or older) per Room

Figure 6.9: The Comparison of Spatial Dashboards (Unit 3300): Patient Fall Rates versus the Percentage of Patient-Days with Older Patients (60 or older) per Room

Figure 6.10: The Comparison of Spatial Dashboards (Unit 4200): Patient Fall Rates versus the Percentage of Patient-Days with Older Patients (60 or older) per Room

6.2.4 Conclusions

The analysis of the spatial dashboards clearly indicated the existence of a third variable (e.g., the physical environment) affecting the spatial patterns of patient falls, beyond the care process- and patient-related variables we have considered. In particular, observing the high rate of falls in certain rooms (e.g., corner rooms located in the back side of the unit), it was clear that there must be some unique physical environmental factors associated with those rooms that have been playing a role in patient falls. The dashboards themselves will be a helpful tool for hospital administrators to use to detect high fall-risk patient rooms or locations, to understand patterns of various factors (from care process- to environment-related factors) that may have been associated with those high fall-risk rooms, and finally to implement appropriate measures to improve any identified fall-risk factors and, therefore, to prevent or reduce patient falls. However, as we start noticing certain spatial patterns of inpatient falls in these units, it was more important to understand that why certain rooms were associated with higher fall rates instead of merely identifying those rooms in units. Therefore, this study implemented a case-control study of patient falls to "unpack" the spatial patterns of patient falls. The goal was to identify specific environmental factors associated with those high fall-risk patient rooms while controlling for fall-related patient characteristics. Section 6.3 shows results from multivariate logistic regression analyses, identifying certain environmental factors associated with fallers and the rooms in which they fell.

6.3 The Group Comparison (Faller versus Non-faller Groups): Intermediate Analyses of Pearson Correlation and Chi-square Tests

Intermediate analyses have been performed to identify any significant differences in variables of interest between the fall and the non-faller group. Pearson correlation analyses with numerical variables identified no significant differences in numerical variables (i.e., age, fall risk score, visibility I, and visibility II) between the faller and non-faller groups (Table 6.4). Chi-square tests of associations of categorical variables of interest between the patient groups also revealed some significant differences in certain fall-related patient characteristics and one environmental factor (Table 6.5). The fall group had less alert ($p < .01$, two-tailed) and more periodically confused ($p < .01$, two-tailed) patients than the non-faller group. In addition, oddly, significantly fewer fallers were in rooms that offer the least accessibility compared to the number of non-fallers in such rooms ($p < .01$, two-tailed). According to our hypothesis relevant to accessibility, more fallers or falls were expected in those rooms. Such phenomenon can be influenced by care process-related factors such as disfavor of such segregated rooms (or rooms with the least accessibility) to admit and care for fall risk patients. As mentioned in Section 5.8, nurses reported that they tend not to admit high fall risk patients to the segregated rooms (e.g., patient rooms in the back of the unit). The segregated rooms are the last option for them to admit their high fall risk patients and it is usually when they don't have any rooms left around the entrance or the busy medication area. Therefore, the impact of the care process-related factor may have masked the true impact of being the least accessible for this study.

Lastly, it is important to point out that, even though we observed such differences in certain variables, they have been statistically controlled during analyses. Therefore, the outcome of each environmental variable can be solely attributable to the environmental factor because the analyses controlled for all other variables in the statistical model.

Table 6.4 Pearson Correlations between Fall Incidence (or Patient Group) and Numerical Variables of Interest

Factor	Patient Group		Correlations
	Falls *N =88* (%)	**Controls *N =148* (%)**	
Patient characteristics			
Age (mean)	65.61	65.77	-.004
Fall risk score (mean)	2.16	2.64	.092
Environmental factors			
Visibility1_headarea (mean)	564.10	566.31	-.013
Distance to Medication (mean)	624.69	620.66	.011

* Correlation significant at the .05 level (two-tailed)
** Correlation significant at the .01 level (two-tailed)

Table 6.5 Chi-square Tests of the Association between Patient Group and Categorical Variables

Factor	Patient Group		χ^2	Gamma
	Falls *N =88* (%)	**Controls *N =148* (%)**		
Patient characteristics				
Gender(M/F)	41/47	56/92	1.747	-.178
LOS at time of falling	4.05	3.18	14.273	.141
Mobility				
Ambulate without problems	18 (20.5)	46 (31.1)	3.15	-.274
Unable to ambulate	4 (4.5)	11 (7.4)	.77	-.255
Ambulate with assistive device	31 (35.2)	47 (31.8)	.30	.078
Ambulate unsteady	35 (39.8)	44 (29.7)	2.50	.219
Mentation				
Alert	59 (67.1)	126 (85.1)	**10.66****	-.476
Unresponsive	0 (0)	1 (.7)	.59	-1.00
Periodic confusion	25 (28.4)	15 (10.1)	**13.09****	.557
Confusion always	4 (4.5)	6 (4.1)	.033	.06
Elimination				
Independent	20 (22.7)	41 (27.7)	.713	-.131
Independent with frequency	6 (6.8)	5 (3.4)	1.46	.353
Needs assistance	54 (61.4)	92 (62.2)	.015	-.017
Incontinence	8 (9.1)	10 (6.8)	.427	.160
Prior fall history				
No	45 (51.1)	85 (57.0)	.884	-.126
Unknown	23 (26.1)	25 (16.8)	2.911	.270
Yes before admission	19 (21.6)	38 (25.5)	.503	-.113
Current fall-related medication				
None	64 (72.7)	102 (68.4)	.384	.092
Anti-convulsant	1 (1.1)	1 (.6)	0.139	0.256
Tranquilizers	3 (3.4)	5 (3.4)	.000	.005
Psychotropics	11 (12.5)	14 (9.4)	.539	.155
Hypnotics	9 (10.23)	26 (17.5)	2.354	-.303

* Correlation significant at the .05 level (two-tailed)

** Correlation significant at the .01 level (two-tailed)

Table 6.5 Continued

Factor	Patient Group		χ^2	Gamma
	Falls *N* =*88* (%)	**Falls *N* =*88* (%)**		
Environmental factors				
Visibility II				
Patients (heads) who are visible from a nearby nurses' station and a corridor, when considering a 210° visual angle from designated seats in a nearby nurses' station (visibility3_h201_1)	21 (23.9)	42 (28.4)	.575	-.117
Patients (heads) who are visible only from a corridor (visibility3_h210_2)	45 (51.1)	79 (53.4)	.111	-.045
Patients (heads) who are NOT visible from outside (both a nearby nurses' station and a corridor, (visibility3_h210_3)	22 (25)	27 (18.2)	1.531	.198
Accessibility				
Patients (body) with the highest accessibility (5.275 or above) (Accessibility_body_1)	19 (21.6)	30 (20.3)	.059	.040
Patients (body) with the second highest accessibility (4.975 – 5.274999) (Accessibility_body_2)	10 (11.4)	12 (8.1)	.692	.185
Patients (body) with the middle range accessibility (4.675 – 4.974999) (Accessibility_body_3)	33 (37.5)	40 (27)	2.833	.237
Patients (body) with the second least accessibility (4.375 – 4.674999) (Accessibility_body_4)	18 (20.5)	31 (20.9)	.008	-.015
Patients (body) with the least accessibility (4.075 – 4.374999) (Accessibility_body_5)	8 (5.4)	35 (39.8)	**7.849****	-.512
Bathroom location (Headwall/footwall side)	8/80	18/130	.531	-.161

* Correlation significant at the .05 level (two-tailed)

** Correlation significant at the .01 level (two-tailed)

6.4 Physical Environmental Risk Factors Increasing the Probability of Experiencing a Fall: A Case-Control Study of Inpatient Falls

6.4.1 Introduction

After performing several intermediate analyses presented in the previous sections (Sections 6.1, 6.2, and 6.3), the investigator conducted a series of robust statistical analyses (i.e., multivariate logistic regression models). The main difference between the intermediate and multivariate logistic regression analyses lies in the changes of the unit of analysis (from the group to the patient) and, therefore, its ability in controlling for other fall-related factors (e.g., patient characteristics) when estimating the impact of environmental factors on patient falls. This section reports results from six representative multivariate logistic regression models (See Table 5.3) tested in this study to identify the best fitting model that reveals significant relationships between variables and the outcome of interest (i.e., patient falls). As mentioned earlier in the section 5.9.2, keeping nine patient-related variables and three environmental variables (i.e., accessibility, distance to medication, and bathroom locations) the same, the six different multivariate logistic models were constructed to test different visibility sub-measures and to identify which visibility sub-measures are significantly associated with patient falls. In total, eight different visibility sub-measures were identified as follows:

Visibility I

- The magnitude of the area in which a patient's **head area** is visible (Visibility I – head area)
- The magnitude of the area in which a patient's **body area** (any parts of the body) is visible (Visibility I – body)

Visibility II

- Whether or not a patient's <u>head area</u> is visible from **any part of a nearby decentralized nurses' station** (with 360 visual angles from any given point) (Visibility2_station)
- Whether or not a patient's <u>head area</u> is visible from **designated seats of a nearby decentralized nurses' station** (with **360 visual angles** from any designated seats)
- Whether or not a patient's <u>head area</u> is visible from **designated seats of a nearby decentralized nurses' station** (with **210 visual angles** from any designated seats)
- Whether or not a patient's <u>body area</u> is visible from **any part of a nearby decentralized nurses' station** (with 360 visual angles from any given point) (Visibility2_station)
- Whether or not a patient's <u>body area</u> is visible from **designated seats of a nearby decentralized nurses' station** (with **360 visual angles** from any designated seats)
- Whether or not a patient's <u>body area</u> is visible from **designated seats of a nearby decentralized nurses' station** (with **210 visual angles** from any designated seats)

These eight different visibility sub-measures were incorporated into six different multivariate logistic models to be tested (See Table 5.3). Our hypotheses were as follows: 1) visual access to a patient's **head area** will be significantly associated with patient falls and 2) visual access to a patient's head area from **designated seats** in a nearby decentralized nurses' station with **a normal visual angle (210 degree)** will be significantly associated with a decrease in the probability of falling.

The following sections will review each model and present the best fitting one within each model and its results. As mentioned in Section 5.9.4, there are several sub-models within each model, depending on how each variable is incorporated (e.g., one variable can be input as numerical, categorical, or group dummy variables). The following section presents and summarizes only a best-fitting sub-model for each model. Further discussion of the findings of these models is reserved for a concluding section at the end.

6.4.2 Results of Six Multivariate Logistic Models (from Step 1)

6.4.2.1 Multivariate Logistic Model 1

6.4.2.1.1 Introduction

A representative multivariate logistic regression equation is as follows:

Model 1

logit(p) = b + b1*(age) + b2*(gender) + b3*(length of stay at time of falling) + b4* (mobility) + b5*(mentation) + b6*(elimination) + b7*(history of falls) + b8*(current fall-related medication) + b9*(fall risk score) + b10*(**Visibility1_headarea**) + b11*(**Visibility2_station**) + b12*(**accessibility_body**) + b13*(**distance to medication**) + b14*(**bathroom location in related to patient**)

This particular model tested the impact of Visibility I_headarea (measured from a patient's head area) and Visibility II_station (concerning where or not a patient head area is visible from any parts of a nearby decentralized nurses' station (with 360 visual angles) with three other environmental variables (i.e., accessibility, distance to medication, and bathroom location) while taking into account key fall-related patient characteristics.

6.4.2.1.2 Results

In this model, none of the visibility measures turned out to be significant. In addition, even though one group (group 5) of the accessibility group (dummy) variables turned out to be significant (p =.003), the trend of the results did not correspond to rational explanations. The results indicated that group 5 (the patients who are least accessible) is associated with significantly less adjust odd ratio (aOR =. 171) of falling than group 1 (patients who are most accessible). There are several possible explanations for these results: 1) variables irrelevant to inpatient falls may have been incorporated into the model: 2) the impact of environmental variables (e.g., visibility measures) may not have been properly controlled for, masking the real impact of the accessibility measure, or 3) this might be correlated with a valid situation that needs further investigation.

In addition, the Chi-square test, presented in Omnibus Tests of Model Coefficients (Table 6.6) indicated that the joint predictive ability of variables of the model is great or statistically significant (p = .006). The Hosmer–Lemeshow test (p = .089) of this model also indicated that the numbers of inpatient falls are not significantly different from those predicted by the model (Table 6.6) and that the overall model fit is good. However, the outcome is quite close to be significant. According to Bewick, Cheek, & Ball, 2005, the Hosmer–Lemeshow test is a commonly used test for assessing the goodness of fit of a model and allows for any number of explanatory variables, which may be continuous or categorical and the goodness of fit of a model measures how well the model describes the response variable. Assessing goodness of fit involves investigating how close values predicted by the model are to the observed values (Bewick, Cheek, & Ball, 2005). The test statistic is calculated as below, as shown in Hosmer and Lemeshow Test in Table 6.6, using the observed and expected counts for both the falls and the non-falls, and has an approximate χ^2 distribution with 8 (=10 - 2) degrees of freedom.

Table 6.6 Model Summaries of Model 1

Omnibus Tests of Model Coefficients (Model 1)

		Chi-square	df	Sig.
Step 1	Step	47.665	26	.006
	Block	47.665	26	.006
	Model	47.665	26	.006

Model Summary (Model 1)

-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
264.078[a]	.183	.249

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	13.736	8	.089

Note: The insignificant result of the Hosmer and Lemeshow Test indicates that the overall model fit is good since the result indicates that the numbers of inpatient falls are not significantly different from those predicted by the model

In this model, two fall-related characteristics turned out to be significant predictors of inpatient falls: 1) mobility 3 (p = .048, one-tailed) and mentation 3 (.001, two-tailed). Even though non-fallers were selected who have similar intrinsic profiles as fallers in terms of age, gender, admitting diagnosis, and DRG, some of the fall-related characteristics were significantly different between the faller and the non-faller groups, resulting in such outcomes. However, these differences were properly controlled through the use of multivariate regression analyses. In other words, multivariate logistic regression analyses test each variable while holding all other variables in the model constant (or controlling for the impact of all other variables in the model). Therefore, significant outcomes of environmental factors in the output are the ones that came out after controlling for the impacts of all other variables in the model.

Table 6.7 The Outcome of Multivariate Logistic Regression Model 1

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Age	-.018	.011	2.792	1	.095	.982
	Gender	-.310	.322	.925	1	.336	.734
	LOS_Falling	.083	.062	1.784	1	.182	1.086
	mobility2	-1.113	1.066	1.090	1	.296	.329
	mobility3	.830	.500	2.760	1	**.097**	**2.294**
	mobility4	.769	.542	2.010	1	.156	2.157
	mentation2	-17.474	40192.970	.000	1	1.000	.000
	mentation3	1.614	.491	10.822	1	**.001**	**5.025**
	mentation4	1.220	.880	1.921	1	.166	3.386
	elimination2	1.287	.807	2.542	1	.111	3.623
	elimination3	-.164	.475	.120	1	.729	.848
	elimination4	1.000	.887	1.271	1	.259	2.718
	priorfallhx2	-.097	.442	.048	1	.826	.907
	priorfallhx3	-.633	.429	2.177	1	.140	.531
	meds2	1.571	1.552	1.025	1	.311	4.813
	meds3	-.381	1.057	.130	1	.718	.683
	meds4	-.070	.541	.017	1	.896	.932
	meds5	-.675	.477	2.007	1	.157	.509
	visibility1_headarea	.003	.004	.422	1	.516	1.003
	Visibility2_station	-.906	.750	1.459	1	.227	.404
	access_cb_5_new_2	-.036	.651	.003	1	.956	.965
	access_cb_5_new_3	.400	.492	.661	1	.416	1.492
	access_cb_5_new_4	-.299	.551	.295	1	.587	.741
	access_cb_5_new_5	-1.769	.632	7.842	1	**.005**	**.171**
	Distance_MED	-.001	.001	.186	1	.666	.999
	Bathroom_Location	-.345	.562	.377	1	.539	.708
	Constant	.083	2.345	.001	1	.972	1.087

a. Variable(s) entered on step 1: Age, Gender, LOS_Falling, mobility2, mobility3, mobility4, mentation2, mentation3, mentation4, elimination2, elimination3, elimination4, priorfallhx2, priorfallhx3, meds2, meds3, meds4, meds5, visibility1_headarea, visibility1_new, access_cb_5_new_2, access_cb_5_new_3, access_cb_5_new_4, access_cb_5_new_5, Distance_MED, Bathroom_Location.

6.4.2.2 <u>Multivariate Logistic Regression Model 2</u>

6.4.2.2.1 Introduction

A representative multivariate logistic regression equation is as follows:

Model 2

logit(p) = b + b1*(age) + b2*(gender) + b3*(length of stay at time of falling) + b4* (mobility) + b5*(mentation) + b6*(elimination) + b7*(history of falls) + b8*(current fall-related medication) + b9*(fall risk score) + b10*(**Visibility1_headarea**) + b11*(**Visibility2_head_seats_360**) + b12*(**accessibility_body**) + b13*(**distance to medication**) + b14*(**bathroom location in related to patient**)

This particular model was testing whether the impact of Visibility I_headarea (measured from a patient's head area) and Visibility II_head_seats_360 (concerning where or not a patient head area is visible from designated seats in a nearby decentralized nurses' station (with 360 visual angles) with three other environmental variables (i.e., accessibility, distance to medication, and bathroom location) while taking into account key fall-related patient characteristics. The only difference between this model and model 1was the Visibility II measure (Visibility II_head_seats_360). Therefore, this model basically tests whether Visibility II_station or Visibility II_head_seats_360 better predicts patient falls.

6.4.2.2.2 Results

In this model, none of the environmental measures turned out to be significant. In fact, the Hosmer–Lemeshow test (p = .001) of this model indicates that the numbers of inpatient falls are significantly different from those predicted by the model (Table 6.8) and that the overall model fit is "not" good. In addition, when comparing models 1 and 2, model 2 does not seem to be any better than model 1, which may mean that the Visibility II_head_seats_360 is not any better than Visibility II_station (Table 6.9). In other words, being able to have visual access to a patient's head from designated seats (with a **360 visual angle** from the designated seats) in a nearby decentralized nurses' station does not matter more than being able to have visual access to a patient's head from anywhere in a nearby decentralized nurses' station.

In this model, the same fall-related characteristics (i.e., mobility 3 and mentation 3) turned out to be significant.

Table 6.8 Model Summaries of Model 2

Omnibus Tests of Model Coefficients (Model 2)

		Chi-square	df	Sig.
Step 1	Step	48.984	27	.006
	Block	48.984	27	.006
	Model	48.984	27	.006

Model Summary (Model 2)

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	262.759[a]	.187	.256

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	25.119	8	.001

Note: The significant result of the Hosmer and Lemeshow Test indicates that the overall model fit is "not" good since the result indicates that the numbers of inpatient falls are significantly different from those predicted by the model

Table 6.9 The Outcome of Multivariate Logistic Regression Model 2

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Age	-.018	.011	2.760	1	.097	.982
	Gender	-.274	.324	.718	1	.397	.760
	LOS_Falling	.080	.063	1.606	1	.205	1.084
	mobility2	-1.405	1.118	1.580	1	.209	.245
	mobility3	.819	.505	2.626	1	.105	2.267
	mobility4	.732	.547	1.788	1	.181	2.079
	mentation2	-18.157	40192.970	.000	1	1.000	.000
	mentation3	1.774	.504	12.384	1	**.000**	**5.894**
	mentation4	1.374	.891	2.379	1	.123	3.951
	elimination2	1.394	.804	3.004	1	**.083**	**4.032**
	elimination3	-.170	.480	.125	1	.723	.844
	elimination4	1.041	.901	1.336	1	.248	2.833
	priorfallhx2	-.199	.455	.191	1	.662	.820
	priorfallhx3	-.577	.429	1.806	1	.179	.561
	meds2	1.221	1.563	.610	1	.435	3.391
	meds3	-.382	1.069	.128	1	.721	.682
	meds4	-.215	.548	.153	1	.695	.807
	meds5	-.676	.478	1.997	1	.158	.509
	visibility1_headarea	-.004	.005	.600	1	.439	.996
	vis2_new_h360_2	-.814	.638	1.630	1	.202	.443
	vis2_new_h360_3	-.369	1.231	.090	1	.764	.691
	access_cb_5_new_2	.549	.683	.646	1	.422	1.731
	access_cb_5_new_3	.490	.504	.947	1	.331	1.633
	access_cb_5_new_4	.212	.625	.115	1	.734	1.236
	access_cb_5_new_5	-.998	.689	2.101	1	.147	.369
	Distance_MED	.000	.001	.060	1	.806	1.000
	Bathroom_Location	-.593	.608	.954	1	.329	.552
	Constant	3.289	3.319	.982	1	.322	26.827

6.4.2.3 Multivariate Logistic Regression Model 3

6.4.2.3.1 Introduction

A representative multivariate logistic regression equation is as follows:

Model 3

logit(p) = b + b1*(age) + b2*(gender) + b3*(length of stay at time of falling) + b4* (mobility) + b5*(mentation) + b6*(elimination) + b7*(history of falls) + b8*(current fall-related medication) + b9*(fall risk score) + b10*(**Visibility1_headarea**) + b11*(**Visibility2_head_seats_210**) + b12*(**accessibility_body**) + b13*(**distance to medication**) + b14*(**bathroom location in related to patient**)

This particular model tests the impact of Visibility I_headarea (measured from a patient's head area) and Visibility II_head_seats_210 (concerning where or not a patient head area is visible from designated seats in a nearby decentralized nurses' station (with a more realistic visual angle of 210 degrees from a given point) with three other environmental variables (i.e., accessibility, distance to medication, and bathroom location) while taking into account key fall-related patient characteristics. The difference between models 2 and 3 is primarily a change of Visibility I measures from Visibility II_head_seats_360 to Visibility II_head_seats_210.

Therefore, the results of this model should indicate which Visibility II measure (between Visibility II_head_seats_360 and Visibility II_head_seats_210) is better associated with patient falls.

6.4.2.3.2 Results

In this model, several environmental measures turned out to be significant (i.e., Visibility_head_seats_210 and accessibility). In addition, the Hosmer–Lemeshow test (p = .408) of this model indicates that the numbers of inpatient falls are "not" significantly different from those predicted by the model (Table 6.10) and that the overall model fit is good.

Considering the fact that the only difference between this model and the other two previous models was the Visibility II measure (Visibility II_head_seats_210), results of this model indicate that Visibility II_head_seats_210 is a significant environmental factor associated with patient falls (table 6.11). In other words, having visual access to a patent's head area from designated seats in a nearby decentralized nurses' station, especially with a more realistic visual angle (210 degree), is a significant predictor of inpatient falls and related to an increase or a decrease of the probability of falling. So far, the model seems to be the best fitting model that includes several significant predictors.

Table 6.10 Model Summaries of Model 3

Omnibus Tests of Model Coefficients (Model 3)

		Chi-square	df	Sig.
Step 1	Step	51.123	27	.003
	Block	51.123	27	.003
	Model	51.123	27	.003

Model Summary (Model 3)

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	260.620[a]	.195	.266

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	8.263	8	.408

Note: The insignificant result of the Hosmer and Lemeshow Test indicates that the overall model fit is good since the result indicates that the numbers of inpatient falls are not significantly different from those predicted by the model

Table 6.11 The Outcome of Multivariate Logistic Regression Model 3

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Age	-.014	.011	1.618	1	.203	.986
	Gender	-.344	.325	1.122	1	.289	.709
	LOS_Falling	.086	.062	1.935	1	.164	1.090
	mobility2	-1.111	1.070	1.079	1	.299	.329
	mobility3	.779	.504	2.387	1	.122	2.180
	mobility4	.746	.547	1.859	1	.173	2.108
	mentation2	-17.268	40192.970	.000	1	1.000	.000
	mentation3	1.570	.491	10.235	1	**.001**	**4.805**
	mentation4	1.024	.890	1.326	1	.250	2.785
	elimination2	1.320	.810	2.659	1	.103	3.745
	elimination3	-.186	.481	.149	1	.699	.830
	elimination4	.959	.890	1.162	1	.281	2.610
	priorfallhx2	-.121	.448	.072	1	.788	.886
	priorfallhx3	-.590	.429	1.885	1	.170	.555
	meds2	1.758	1.555	1.278	1	.258	5.802
	meds3	-.388	1.053	.136	1	.713	.679
	meds4	-.058	.544	.011	1	.915	.944
	meds5	-.752	.484	2.416	1	.120	.471
	visibility1_headarea	.011	.006	3.145	1	.076	1.011
	vis3_new_h210_2	1.496	.783	3.653	1	**.056**	**4.462**
	vis3_new_h210_3	3.896	1.787	4.755	1	**.029**	**49.207**
	access_cb_5_new_2	1.580	.893	3.131	1	**.077**	**4.854**
	access_cb_5_new_3	1.061	.611	3.010	1	**.083**	**2.889**
	access_cb_5_new_4	1.266	.829	2.331	1	.127	3.547
	access_cb_5_new_5	-.090	.848	.011	1	.915	.914
	Distance_MED	-.002	.002	1.483	1	.223	.998
	Bathroom_Location	-.674	.637	1.121	1	.290	.510
	Constant	-6.405	4.177	2.352	1	.125	.002

6.4.2.4 Multivariate Logistic Regression Model 4

6.4.2.4.1 Introduction

A representative multivariate logistic regression equation is as follows:

Model 4

logit(p) = b + b1*(age) + b2*(gender) + b3*(length of stay at time of falling) + b4* (mobility) + b5*(mentation) + b6*(elimination) + b7*(history of falls) + b8*(current fall-related medication) + b9*(fall risk score) + b10*(**Visibility1_bodyarea**) + b11*(**Visibility2_station**) + b12*(**accessibility_body**) + b13*(**distance to medication**) + b14*(**bathroom location in related to patient**)

From this particular model, we have started to incorporate the Visibility I measure (Visibility I_bodyarea). The previous three models have incorporated the Visibility I measure (Visibility I_headarea). It is particularly useful to compare this model with Model 1 since the only difference between the models is the Visibility I measure. As Model 1 tested the impact of Visibility I_headarea, Model 4 tests the impact of the other Visibility I measure (Visibility I_bodyaera) while keeping other variables the same. Therefore, the results of this model may indicate which Visibility I measure works better to predict inpatient falls.

6.4.2.4.2 Results

Results of this model were quite similar to the ones in the Model 1, which indicates that the Visibility_body area measure does not necessarily predict inpatient falls better than the Visibility_head area measure (Table 6.13). Like model 1, none of visibility measures turned out to be significant. In addition, even though one group (group 5) of the accessibility group (dummy) variables turned out to be significant (p =.003), the trend of the result did not correspond with rational explanations. The result indicated that group 5 (patients who are **least** accessible) is associated with significantly less adjust odd ratio (aOR =. 171) of falling than the group 1 (patients who are most accessible). As mentioned earlier, the several explanations will be reserved for the discussion of the results. The Hosmer–Lemeshow test ($p = .408$) of this model indicates that the numbers of inpatient falls are “not” significantly different from those predicted by the model (Table 6.12) and that the overall model fit is good.

Table 6.12 Model Summaries of Model 4

Omnibus Tests of Model Coefficients (Model 4)

		Chi-square	df	Sig.
Step 1	Step	48.182	26	.005
	Block	48.182	26	.005
	Model	48.182	26	.005

Model Summary (Model 4)

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	263.560[a]	.185	.252

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	7.351	8	.499

Note: The insignificant result of the Hosmer and Lemeshow Test indicates that the overall model fit is good since the result indicates that the numbers of inpatient falls are not significantly different from those predicted by the model

Table 6.13 The Outcome of Multivariate Logistic Regression Model 4

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Age	-.018	.011	2.921	1	.087	.982
	Gender	-.309	.323	.917	1	.338	.734
	LOS_Falling	.078	.062	1.598	1	.206	1.082
	mobility2	-1.152	1.076	1.146	1	.284	.316
	mobility3	.840	.500	2.818	1	**.093**	**2.316**
	mobility4	.797	.545	2.141	1	.143	2.220
	mentation2	-17.606	40192.970	.000	1	1.000	.000
	mentation3	1.640	.491	11.150	1	**.001**	**5.156**
	mentation4	1.284	.882	2.119	1	.145	3.612
	elimination2	1.364	.808	2.851	1	.091	3.912
	elimination3	-.149	.477	.097	1	.755	.862
	elimination4	1.014	.890	1.298	1	.255	2.757
	priorfallhx2	-.144	.449	.103	1	.748	.866
	priorfallhx3	-.633	.430	2.172	1	.141	.531
	meds2	1.578	1.552	1.033	1	.309	4.843
	meds3	-.322	1.063	.092	1	.762	.725
	meds4	-.122	.544	.050	1	.822	.885
	meds5	-.613	.483	1.611	1	.204	.542
	visibility1body	.002	.003	.935	1	.334	1.002
	Visibility2_station	-.982	.633	2.408	1	.121	.374
	access_cb_5_new_2	.156	.596	.068	1	.794	1.168
	access_cb_5_new_3	.514	.513	1.003	1	.317	1.671
	access_cb_5_new_4	-.062	.558	.012	1	.911	.940
	access_cb_5_new_5	-1.378	.632	4.755	1	**.029**	**.252**
	Distance_MED	.000	.001	.116	1	.733	1.000
	Bathroom_Location	-.424	.566	.561	1	.454	.654
	Constant	-.236	2.109	.013	1	.911	.789

6.4.2.5 Multivariate Logistic Regression Model 5

6.4.2.5.1 Introduction

A representative multivariate logistic regression equation is as follows:

Model 5

logit(p) = b + b1*(age) + b2*(gender) + b3*(length of stay at time of falling) + b4* (mobility) + b5*(mentation) + b6*(elimination) + b7*(history of falls) + b8*(current fall-related medication) + b9*(fall risk score) + b10*(**Visibility1_bodyarea**) + b11*(**Visibility2_body_seats_360**) + b12*(**accessibility_body**) + b13*(**distance to medication**) + b14*(**bathroom location in related to patient**)

6.4.2.5.2 Results

The results of this model were quite similar to the ones in the Models 1 and 4, which also indicate that the Visibility_body area measure is not necessarily a better predictor for inpatient falls than the Visibility_head area measure (Table 6.15). In addition, in comparison with Model 4, it seems that the Visibility II_body_seats_360 measure is also not necessarily better than the Visibility II_station measure. As with Models 1 and 4, none of visibility measures turned out to be significant. In addition, even though one group (group 5) of the accessibility group (dummy) variables turned out to be significant (p =.048), the trend of the result did not correspond with rational explanations. The Hosmer–Lemeshow test (p = .558) of this model indicates that the numbers of inpatient falls are “not” significantly different from those predicted by the model (Table 6.14) and that the overall model fit is good.

Table 6.14 Model Summaries of Model 5

Omnibus Tests of Model Coefficients (Model 5)

		Chi-square	df	Sig.
Step 1	Step	45.736	26	.010
	Block	45.736	26	.010
	Model	45.736	26	.010

Model Summary (Model 5)

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	266.006[a]	.176	.240

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	6.806	8	.558

Note: The insignificant result of the Hosmer and Lemeshow Test indicates that the overall model fit is good since the result indicates that the numbers of inpatient falls are not significantly different from those predicted by the model

Table 6.15 The Outcome of Multivariate Logistic Regression Model 5

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Age	-.018	.011	2.694	1	.101	.983
	Gender	-.255	.320	.637	1	.425	.775
	LOS_Falling	.082	.061	1.767	1	.184	1.085
	mobility2	-1.224	1.075	1.297	1	.255	.294
	mobility3	.839	.499	2.826	1	.093	2.313
	mobility4	.727	.542	1.798	1	.180	2.070
	mentation2	-17.814	40192.970	.000	1	1.000	.000
	mentation3	1.666	.491	11.503	1	.001	5.289
	mentation4	1.248	.874	2.038	1	.153	3.483
	elimination2	1.190	.800	2.214	1	.137	3.288
	elimination3	-.216	.473	.210	1	.647	.805
	elimination4	.973	.887	1.202	1	.273	2.645
	priorfallhx2	-.083	.443	.035	1	.851	.920
	priorfallhx3	-.592	.427	1.928	1	.165	.553
	meds2	1.238	1.552	.637	1	.425	3.450
	meds3	-.515	1.057	.238	1	.626	.597
	meds4	-.123	.541	.052	1	.820	.884
	meds5	-.742	.478	2.409	1	.121	.476
	visibility1body	-.001	.003	.082	1	.775	.999
	visibility2_new_a360	-.008	.488	.000	1	.987	.992
	access_cb_5_new_2	.065	.682	.009	1	.924	1.067
	access_cb_5_new_3	.178	.486	.135	1	.714	1.195
	access_cb_5_new_4	-.221	.658	.113	1	.737	.802
	access_cb_5_new_5	-1.608	.814	3.904	1	**.048**	**.200**
	Distance_MED	.000	.001	.008	1	.928	1.000
	Bathroom_Location	-.293	.582	.254	1	.614	.746
	Constant	1.468	3.107	.223	1	.637	4.342

a. Variable(s) entered on step 1: Age, Gender, LOS_Falling, mobility2, mobility3, mobility4, mentation2, mentation3, mentation4, elimination2, elimination3, elimination4, priorfallhx2, priorfallhx3, meds2, meds3, meds4, meds5, visibility1body, visibility2_new_a360, access_cb_5_new_2, access_cb_5_new_3, access_cb_5_new_4, access_cb_5_new_5, Distance_MED, Bathroom_Location.

6.4.2.6 Multivariate Logistic Regression Model 6

6.4.2.6.1 Introduction

A representative multivariate logistic regression equation is as follows:

Model 6

logit(p) = b + b1*(age) + b2*(gender) + b3*(length of stay at time of falling) + b4* (mobility) + b5*(mentation) + b6*(elimination) + b7*(history of falls) + b8*(current fall-related medication) + b9*(fall risk score) + b10*(**Visibility1_bodyarea**) + b11*(**Visibility2_body_seats_210**) + b12*(**accessibility_body**) + b13*(**distance to medication**) + b14*(**bathroom location in related to patient**)

This particular model was testing the impact of Visibility I_body area (measured from a patient's head area) and Visibility II_body_seats_210 (concerning where or not any part of a patient's body is visible from designated seats in a nearby decentralized nurses' station (with a more realistic visual angle of 210 degrees from a given point), in addition to three other environmental variables (i.e., accessibility, distance to medication, and bathroom location) while taking into account key fall-related patient characteristics. Considering the fact that the only difference between Models 5 and 6 is a change of Visibility I measures from Visibility II_body_seats_360 to Visibility II_body_seats_210), results of this model should indicate which Visibility II measure is more closely associated with patient falls.

6.4.2.6.2 Results

Results of this model indicated that the visibility measure (Visibility II_body_seats_210) better predicts inpatient falls, as also seen from the results of Model 3. As inputting the visibility measure (Visibility II_body_seats_210), several environmental measures were identified as significant predictors (i.e., Visibility_body_seats_210 and accessibility group 3) for inpatient falls (Table 5.17). In other words, having visual access to any part of a patient's body from designated seats in a nearby decentralized nurses' station, especially with the more realistic visual angle (210 degrees), is a significant predictor of inpatient falls. The Hosmer–Lemeshow test (*p* = .335) of this model indicated that the numbers of inpatient falls are "not" significantly different from those predicted by the model (Table 6.14) and that the overall model fit is good (Table 5.16).

Table 6.16 Model Summaries of Model 6

Omnibus Tests of Model Coefficients (Model 6)

		Chi-square	df	Sig.
Step 1	Step	55.465	26	.001
	Block	55.465	26	.001
	Model	55.465	26	.001

Model Summary (Model 6)

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	256.277[a]	.209	.286

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	9.092	8	.335

Note: The insignificant result of the Hosmer and Lemeshow Test indicates that the overall model fit is good since the result indicates that the numbers of inpatient falls are not significantly different from those predicted by the model

Table 6.17 The Outcome of Multivariate Logistic Regression Model 6

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Age	-.016	.011	1.963	1	.161	.985
	Gender	-.315	.326	.930	1	.335	.730
	LOS_Falling	.077	.063	1.473	1	.225	1.080
	mobility2	-1.263	1.080	1.368	1	.242	.283
	mobility3	.793	.506	2.452	1	.117	2.210
	mobility4	.765	.553	1.914	1	.167	2.149
	mentation2	-16.921	40192.970	.000	1	1.000	.000
	mentation3	1.736	.497	12.206	1	.000	5.676
	mentation4	1.210	.887	1.862	1	.172	3.352
	elimination2	1.355	.809	2.803	1	.094	3.877
	elimination3	-.139	.489	.081	1	.776	.870
	elimination4	.931	.888	1.099	1	.295	2.536
	priorfallhx2	-.157	.460	.117	1	.733	.855
	priorfallhx3	-.494	.432	1.312	1	.252	.610
	meds2	1.216	1.539	.624	1	.430	3.373
	meds3	-.164	1.065	.024	1	.878	.849
	meds4	-.126	.564	.050	1	.823	.881
	meds5	-.542	.487	1.236	1	.266	.582
	visibility1body	.003	.002	2.766	1	.096	1.003
	vis3_new_a210_2	1.673	.559	8.947	1	**.003**	**5.328**
	access_cb_5_new_2	.880	.663	1.763	1	.184	2.411
	access_cb_5_new_3	1.300	.605	4.620	1	**.032**	**3.668**
	access_cb_5_new_4	.694	.631	1.209	1	.272	2.002
	access_cb_5_new_5	-.792	.688	1.326	1	.249	.453
	Distance_MED	-.001	.001	.167	1	.682	.999
	Bathroom_Location	-.155	.572	.074	1	.786	.856
	Constant	-3.441	2.470	1.940	1	.164	.032

6.4.3 Main Results from Step 1 (Based on Comparisons of the Six Models)

Results of the six different models revealed significant physical environmental factors associated with inpatient falls. In addition, the analysis identified which Visibility measures were significantly associated with inpatient falls. This section will review how the results of the six models contributed to identifying certain visibility and other physical environmental measures associated with inpatient falls.

6.4.3.1 Visibility I versus Visibility II measures

None of Visibility I measures turned out be significant in any of the six models, while several Visibility II measures did emerge as significant. The results demonstrated that Visibility II measures concerning whether or not a patient is visible from "functional" spaces (e.g., a nearby decentralized nurses' station or a corridor) better predict inpatient falls than the magnitude of the area in which a patient is visible within a unit. For example, if there are two patients with the similar spatial areas in the unit from which each patient is visible, a patient who is visible from designated seats in a nearby decentralized nurses' station (with 210 degree visual angles) will be less likely to experience a fall.

6.4.3.2 Among Visibility II Measures

In both Models 3 and 6, the Visibility II measure concerning visual access from designated seats in a nearby decentralized nurses' station (with 210 visual angles from the seats) was a significant predictor of inpatient falls. The other two visibility measures, concerning the visual access from any part of nurses' station (VisibilityII_station) and from designated seats in a nearby decentralized nurses' station (with 360 visual angles) (Visibility_seats_360) were not associated with inpatient falls. In other words, having visual access to a patient from designated seats in a nearby decentralized nurses' station (with 210 visual angles from the seats) is a significant predictor of whether the patient will sustain a fall or not. The remaining question then was what parts of the patient needed to be visible. Models 3 and 6 demonstrated that both visibility to a patient's head area and to any parts of the body matter but, according to Model 3, certain patients whose head areas were not visible (group 3 in the variable of Visibility_head_seats_210) were associated with an extremely significant increase in the probability of falling. Model 3 demonstrates that when a patient's head area is visible (e.g., the variable visiblity_head_seats_210), patients could be categorized into three groups: 1) group 1: patients whose head areas are visible from both a nearby decentralized nurses' station and corridors, 2) group 2: patients whose head areas are visible only from corridors, and 3) group 3: patients whose head areas are not visible from either nurses' stations and corridors. This categorization revealed that patient group 3 was associated with an extreme increase in the probability of falling. On the other hand, model 6 demonstrates that when considering the visibility to any parts of a patient's body (e.g., the variable of Visiblity_body_seats_210), patients could be categorized into only two groups: 1) group 1: patients whose body areas are visible from both a nearby decentralized nurses' station and corridors and 2) group 2: patients whose body areas are visible only from corridors. Patient group 3 does not exist because, in all cases, some parts of patients were visible from corridors. In summary, Model 3's visibility variable concerning the visual access to a patient's head revealed one patient group (patient group 3 of Visibility II _body_seats_210) and the relevant physical environmental factor that increases the probability of falling that was otherwise non-discoverable from Model 6.

Therefore, Model 3 will be subject to further interpretation and discussion in the following section.

6.4.4 Results from the Best Predictive Model (Model 3) from Step 1

This section discusses findings of the multivariate logistic Model 3 that worked best in explaining the relationship between various physical environmental measures of interest and the binary dependent variable (i.e., a fall sustained or not). Model 3 included visibility variables concerning visual access to a patient's head from designated seats at nurses' stations, allowing a 210° visual angle from the seats. The multivariate model calculated adjusted odds ratios (aORs)—approximations of the relative risk—with 95% confidence intervals (CIs) to identify the relative risk of falling per each variable of interest within the model. The calculated adjusted odds ratios (aORs) were used to calculate a probability of falling according to each variable of interest.

The findings of the multivariate analysis, shown in Table 6.18, identified four significant physical environmental factors associated with an increased risk of falling while controlling for all other variables in the model. In addition, one patient-related factor (mentation) was also associated with an increased risk of falling, while controlling for all other variables in the model.

1 Visibility II to patient

1.1 Compared to patients who were visible from both corridors and nurses' stations (the patient group 1), patients who were **visible only from a corridor** (patient group 2) were much more likely to experience a fall (p = .028, one-tailed), controlling for all the other variables in the model. The statistical findings, shown in Table 6.18, demonstrated that the odds of falling were **4.5 times greater** for patients who were visible only from corridors (the patient group 2) than patients who were visible from both corridors and nurses' stations (the patient group 1), controlling for all other variables in the model (see Table 6.18). When it is converted to the probability of experiencing a fall, the outcome shows that, for the average patient (as determined by the mean values of all the model variables), the probability of falling is **36% higher** when a patient is visible only from a corridor compared to when a patient visible from both nurses' stations and corridors.

1.2 Compared to patients who were visible from both nurses' stations and corridors (patient group 1), patients who were **not visible from the outside at all** (neither from the corridor or the nurses' station) (the patient group 3) were much more likely to experience a fall ($p = .015$, one-tailed), controlling for all other variables in the model. The statistical findings, shown in Table 6.18, also demonstrated that the odds of falling were **49 times greater** for patients who were not visible from either the corridors or the nurses' stations (patient group 3) than patients who were visible from both corridors and nurses' stations (patient group 1), controlling for all other variables in the model. For the average patient (again, as determined by the mean values of all the model variables), the probability of experiencing a fall was **74% higher** when a patient is not visible at all from outside the room (from neither corridors nor nurses' stations) compared to a patient who is visible from both nurses' stations and corridors.

2 Accessibility to patient

2.1 Compared to patients with the highest accessibility (patient group 1), patients with lower accessibility (patient groups 2 and 3) had a higher probability of experiencing a fall (p = .039 and .043, one-tailed, respectively), controlling for all other variables in the model. The statistical findings, shown in Table 6.18, also demonstrated that, compared to patients who were the most highly accessible (patient group 1 – accessibility range at 5.275 or above), the odds of falling were almost **5 times greater** for patients who were less accessible (patient group 2 –accessibility range was between 4.975 – 5.274999) and **3 times greater** for patients with even less accessibility (patient group 3 – the accessibility range was between 4.675 – 4.974999). For the average patient (again, as determined by the mean values of all the model variables), the probability of experiencing a fall **increased 24 %** (for patient group 3) **to 37%** (for patient group 2) when a patient was less accessible (patient groups 2 and 3) compared to when a patient was the most accessible (patient group 1). However, oddly, compared to patients with the highest accessibility (patient group 1), patients with the lowest accessibility (patient groups 4 and 5) did not have a statistically significant increase in the probability of falling. Detailed discussion in regard to this finding is in Chapter 7 Discussion and Conclusions.

3 Mentation

3.1 Patients experiencing periodic confusion had a much higher probability of experiencing a fall (p = .0005, one-tailed) than those who were alert (patient group 1), controlling for all other variables in the model. The odds of falling were almost **5 times greater** for patients with periodic confusion (mentation patient group 3) than patients who were alert (mentation patient group 1). For the average patient (again, as determined by the mean values of all the model variables), the probability of experiencing a fall **increased 36.9 %** for patients with periodic confusion (mentation patient group 3) when compared to patients who were alert (mentation patient group 1).

Table 6.18 Multivariate Model of Environmental and Fall-related Patient Factors Associated with Falling in the Hospital

Factor	**Falls *N* =88 (%)**	**Controls *N* =148 (%)**	**B**	**S.E.**	**Wald**	**Sig.**	**aOR**	**95% C.I.for EXP(B)**	
								Lower	**Upper**
Patient characteristics									
Age (mean)	65.61	65.77	-.014	.011	1.618	.203	.986	.965	1.008
Gender(M/F)	41/47	56/92	-.344	.325	1.122	.289	.709	.375	1.340
LOS at time of falling (mean)	4.05	3.18	.086	.062	1.935	.164	1.090	.966	1.230
Mobility									
Ambulate without problems	18 (20.5)	46 (31.1)							
Unable to ambulate	4 (4.5)	11 (7.4)	-1.111	1.070	1.079	.299	.329	.040	2.680
Ambulate with assistive device	31 (35.2)	47 (31.8)	.779	.504	2.387	.122	2.180	.811	5.859
Ambulate unsteadily	35 (39.8)	44 (29.7)	.746	.547	1.859	.173	2.108	.722	6.162
Mentation									
Alert	59 (67.1)	126 (85.1)							
Unresponsive	0 (0)	1 (.7)	-17.268	40192.97	.000	1.000	.000	.000	.
Periodic confusion	25 (28.4)	15 (10.1)	1.570	.491	10.235	**.001**	**4.805**	1.837	12.572
Always confused	4 (4.5)	6 (4.1)	1.024	.890	1.326	.250	2.785	.487	15.926
Elimination									
Independent	20 (22.7)	41 (27.7)							
Independent with frequency	6 (6.8)	5 (3.4)	1.320	.810	2.659	.103	3.745	.766	18.313
Needs assistance	54 (61.4)	92 (62.2)	-.186	.481	.149	.699	.830	.324	2.131
Incontinent	8 (9.1)	10 (6.8)	.959	.890	1.162	.281	2.610	.456	14.934
Prior fall history									
None	45 (51.1)	85 (57.0)							
Unknown	23 (26.1)	25 (16.8)	-.121	.448	.072	.788	.886	.368	2.134
Yes before admission	19 (21.6)	38 (25.5)	-.590	.429	1.885	.170	.555	.239	1.287
Current fall-related medication									
None	64 (72.7)	102 (68.4)							
Anti-convulsant	1 (1.1)	1 (.6)	1.758	1.555	1.278	.258	5.802	.275	122.313
Tranquilizers	3 (3.4)	5 (3.4)	-.388	1.053	.136	.713	.679	.086	5.341
Psychotropics	11 (12.5)	14 (9.4)	-.058	.544	.011	.915	.944	.325	2.741

Hypnotics	9 (10.23)	26 (17.5)	-.752	.484	2.416	.120	.471	.182	1.217
Fall risk score (mean)	2.16	2.64							
Environmental factors									
Visibility1_headarea (mean)	564.10	566.31	.011	.006	3.145	.076	1.011	.999	1.023
Visibility2									
Visibility2 group 1 Patients (heads) who are visible from nurses' stations, when considering a 210° visual angle from designated seats in nurses' stations (Visibility2_h201_1)	21 (23.9)	42 (28.4)	-	-	-	-	-	-	-
Visibility2 group 2 Patients (heads) who are visible only from a corridor, when considering a 210° visual angle from designated seats in nurses' stations (visibility2_h210_2)	45 (51.1)	79 (53.4)	1.496	.783	3.653	**.056**	**4.462**	.963	20.687
Visibility2 group 3 Patients (heads) who are NOT visible at all from outside (both a nearby nurses' station and a corridor), when considering a 210° visual angle from designated seats in nurses' stations (visibility2_h210_3)	22 (25)	27 (18.2)	3.896	1.787	4.755	**.029**	**49.207**	1.483	1632.768

Accessibility									
Accessibility group 1 **Patients (body) with the highest accessibility** (5.275 or above) (Accessibility_body_1: access_cb_5_1)	19 (21.6)	30 (20.3)	-	-	-	-	-	-	-
Accessibility group 2 **Patients (body) with the second highest accessibility** (4.975 – 5.274999) (Accessibility_body_2: access_cb_5_2)	10 (11.4)	12 (8.1)	1.580	.893	3.131	**.077**	**4.854**	.844	27.927
Accessibility group 3 **Patients (body) with the middle range accessibility** (4.675 – 4.974999) (Accessibility_body_3: access_cb_5_3)	33 (37.5)	40 (27)	1.061	.611	3.010	**.083**	**2.889**	.871	9.577
Accessibility group 4 **Patients (body) with the second least accessibility** (4.375 – 4.674999) (Accessibility_body_4: access_cb_5_4)	18 (20.5)	31 (20.9)	1.266	.829	2.331	.127	3.547	.698	18.021
Accessibility group 5 **Patients (body) with the least accessibility** (4.075 – 4.374999) (Accessibility_body_5: access_cb_5_5)	8 (5.4)	35 (39.8)	-.090	.848	.011	.915	.914	.173	4.815
Distance to Medication (mean)	624.69	620.66	-.002	.002	1.483	.223	.998	.995	1.001
Bathroom location (Headwall/footwall side)	8/80	18/130	-.674	.637	1.121	.290	.510	.146	1.776
Constant			-6.405	4.177	2.352	.125	.002		

6.5 Results of the Sub-Group Analysis: Only with Unassisted Falls (Step 2)

6.5.1 Introduction

As reviewed in Section 5.5 Hypotheses, the current study hypothesized that unit- and room-related physical environmental factors (e.g., visibility and accessibility to a patient) will be associated with the risk of falling, based on one underlying assumption: The unit- and room-related physical environmental factors are likely to affect staff's ability to intervene on a patient's behalf before a fall occurs as they may affect staff visual surveillance and proximity to patients. The validity of this assumption or hypothesis is not empirically or statistically tested in this study but it seemed worthwhile testing the association between variables of interest and the outcome with only unassisted inpatient falls because, clearly, assisted falls are not related to staff's ability to intervene before a fall occurs. Those falls occurred while staff was assisting patients with their activities.

Seventy-eight out of 88 inpatient falls were unassisted (See Table 6.1). Therefore, only those 78 unassisted falls and their counterparts (non-fallers) were included in this analysis. After identifying the most predictive out of the six models, we further tested the Model 3 to determine the differences in results between the data sets or to identify where or not the environmental fall risk predictors identified with the data set of 88 falls are still significant with the data set of 78 unassisted falls. It is expected to show similar results, since the majority of the 88 inpatient falls were unassisted.

6.5.2 Results

A multivariate analysis involving data from the 78 unassisted falls identified additional fall predictors (i.e., mobility patient group 2 and accessibility patient group 4) (See Table 6.19). In addition, the association between some environmental variables (e.g., accessibility measures) and inpatient falls was shown to be even stronger as indicated by associated statistical significances.

6.5.2.1 Variables (or predictors) Already Identified in Previous Analyses

Predictors identified from previous analyses held their significant associations with inpatient falls with slightly better magnitudes or significances.

1 Visibility II to patient

1.1 Compared to patients who were visible from both corridors and nurses' stations (the patient group 1), patients who were **visible only from a corridor** (patient group 2) were much likely to experience a fall (p = .026, one-tailed), controlling for all the other variables in the model. The statistical findings, shown in Table 6.19, demonstrated that the odds of falling were **5.3 times greater** for patients who were visible only from corridors (the patient group 2) than patients who were visible from both corridors and nurses' stations (the patient group 1), controlling for all other variables in the model (see Table 6.19). When it was converted to the probability of experiencing a fall, the outcome shows that for the average patient (again, as determined by the mean values of all the model variables), the probability of falling is **35% higher** when a patient is visible only from a corridor compared to when a patient visible from both nurses' stations and corridors.

1.2 Compared to patients who were visible from both corridors and nurses' stations (patient group 1), patients who were **not visible from the outside at all** (neither from the corridor or the nurses' station) (the patient group 3) were much more likely to experience a fall (p = .012, one-tailed) controlling for all other variables in the model. The statistical findings, shown in Table 6.19, also demonstrated that the odds of falling were **87.9 times greater** for patients who were not visible from either the corridors or the nurses' stations (patient group 3) than patients who were visible from both corridors and nurses' stations (patient group 1), controlling for all other variables in the model. For the average patient (again, as determined by the mean values of all the model variables), the probability of experiencing a fall **increases 78%** when a patient is not visible at all from outside the room (from neither corridors nor nurses' stations) compared to a patient who is visible from both nurses' stations and corridors.

2 Accessibility to patient

2.1 Compared with the highest accessibility patients (patient group 1), patients with lower accessibility (patient groups 2 and 3) had a higher probability of experiencing a fall ($p = .029$ and $.018$, one-tailed, respectively), controlling for all other variables in the model. The statistical findings, shown in Table 4.1, also demonstrated that, compared to patients who were the most highly accessible (patient group 1 – the accessibility range was 5.275 or above), the odds of falling were almost **6.2 times greater** for patients who were less accessible (patient group 2 – the accessibility range was between 4.975 – 5.274999) and **4 times greater** for patients with even less accessibility (patient group 3 – the accessibility range was between 4.675 – 4.974999). For the average patient (again, as determined by the mean values of all the model variables), the probability of experiencing a fall is **32% higher** for the patient group 3 and **43% higher** for the patient group 2 compared to when a patient was the most accessible (the patient group 1).

3 Mentation

3.1 Patients experiencing periodic confusion had a much higher probability of experiencing a fall (p = .0005, one-tailed) than those who were alert (patient group 1), controlling for all other variables in the model. The odds of falling were 6.234 **times greater** for patients with periodic confusion (mentation patient group 3) than patients who were alert (mentation patient group 1). The probability of experiencing a fall **increased 36.9 %** for patients with periodic confusion (mentation patient group 3) when compared to patients who were alert (mentation patient group 1).

6.5.2.2 Additional Variables (or Predictors) Identified from this Analysis

1 Accessibility to patient

1.1 In addition to patient groups 2 and 3, patient group 4 (patients with the second least accessibility) had a higher probability of experiencing a fall (p = .038, one-tailed) than those with the highest accessibility (patient group 1), controlling for all other variables in the model. The statistical findings, shown in Table **4.1**, demonstrated that the odds of falling were almost **5.3 times greater** for patients who were the second least accessible (patient group 4 – the accessibility range was between 4.375 – 4.675) than patients who were the most highly accessible (patient group 1 – the accessibility range was 5.275 or above). For the average patient (again, as determined by the mean values of all the model variables), the probability of experiencing a fall **increased 39%** when a patient was less accessible (patient group 4) compared to when a patient was the most accessible (patient group 1). Again, there was not a statistically significant increase in the probability of falling for patient group 5 (patients with the least accessibility) when compared to patient group 1 (patients with the most accessibility). However, it is important to note that the odds of falling for patient group 5 were still greater than patient group 1 but were simply not *statistically* significant. Therefore, we observe a consistent trend– having greater odds of falling when patients were less accessible than the group with the most highly accessible (patient group 1.

2 Mobility

2.1 Patients ambulating with an assistive device (patient group 3) had a higher probability of experiencing a fall ($p = .036$, one-tailed) than those ambulating without problems (patient group 1), controlling for all other variables in the model. The odds of falling were almost **2.61 times greater** for patients ambulating with an assistive device (the mobility patient group 3) than patients ambulating without problems (the mobility patient group 1). The probability of experiencing a fall **increased 22%** for patients ambulating with an assistive device when compared to patients who ambulating without problems.

Table 6.19 The Outcome of Sub-Group Analysis (with Only 78 Unassisted Inpatient Falls): Multivariate Model of Environmental and Fall-related Patient Factors Associated with Falling in the Hospital

Factor	Falls *N* =*78* (%)	Controls *N* =*131* (%)	B	S.E.	Wald	Sig.	aOR	95% C.I.for EXP(B) Lower	Upper
Patient characteristics									
Age (mean)	65.07	64.67	-.008	.012	.400	.527	.992	.970	1.016
Gender(M/F)	37 (47.4)/41 (52.6)	51 (38.9)/80 (61.1)	-.354	.363	.947	.331	.702	.344	1.431
LOS at time of falling (mean)	4.16	3.22	.099	.074	1.787	.181	1.104	.955	1.276
Mobility									
Ambulate without problems	16 (20.5)	41 (31.3)							
Unable to ambulate	3 (3.8)	10 (7.6)	-1.244	1.142	1.187	.276	.288	.031	2.702
Ambulate with assistive device	27 (34.6)	40 (30.5)	.914	.541	2.850	**.091**	**2.494**	.863	7.207
Ambulate unsteadily	32 (41.0)	40 (30.5)	.719	.593	1.469	.226	2.053	.642	6.568
Mentation									
Alert	51 (65.4)	110 (84.0)							
Unresponsive	0 (0)	1 (.8)	-16.245	40192.97	.000	1.000	.000	.000	.
Periodic confusion	23 (29.5)	14 (10.7)	1.830	.556	10.824	**.001**	**6.234**	2.096	18.547
Always confused	4 (5.1)	6 (4.6)	1.416	.926	2.339	.126	4.120	.671	25.285
Elimination									
Independent	20 (25.6)	37 (28.2)							
Independent with frequency	5 (6.4)	5 (3.8)	.958	.888	1.165	.280	2.607	.458	14.853
Needs assistance	46 (59.0)	79 (60.3)	-.374	.509	.541	.462	.688	.254	1.865
Incontinent	7 (9.0)	10 (7.6)	.635	.919	.477	.490	1.886	.311	11.427
Prior fall history									
No	41 (52.6)	74 (56.5)							
Unknown	18 (23.1)	23 (17.6)	-.672	.509	1.740	.187	.511	.188	1.386
Yes before admission	19 (24.4)	34 (26.0)	-.814	.490	2.754	.097	.443	.169	1.159
Current fall-related medication									
None	58 (74.4)	91 (69.5)							

Anti-convulsant	1 (1.3)	1 (.8)	2.134	1.596	1.787	.181	8.449	.370	192.997
Tranquilizers	2 (2.6)	5 (3.8)	-.553	1.187	.217	.642	.575	.056	5.897
Psychotropics	9 (11.5)	12 (9.2)	-.174	.605	.082	.774	.841	.257	2.754
Hypnotics	8 (10.3)	22 (16.8)	-.812	.551	2.173	.140	.444	.151	1.307
Fall risk score (mean)	2.18	2.0							
Environmental factors									
Visibility1_headarea (mean)	568.7	568.4	.011	.007	2.782	.095	1.011	.998	1.024
Visibility2									
Visibility2 group1 Patients (heads) who are visible from nurses' stations, when considering a 210° visual angle from designated seats in nurses' stations (Visibility2_h201_1)	19 (24.4)	38 (29.0)	-	-	-	-	-	-	-
Visibility group 2 Patients (heads) who are visible only from only corridors, when considering a 210° visual angle from designated seats in nurses' stations (visibility2_h210_2)	39 (50.0)	71 (54.2)	1.590	.870	3.337	**.068**	**4.903**	.891	26.998
Visibility group 3 Patients (heads) who are NOT visible at all from outside (both a nearby nurses' station and a corridor, when considering a 210° visual angle from designated seats in nurses' stations (visibility2_h210_3)	20 (25.6)	22 (16.82)	4.375	1.991	4.828	**.028**	**79.464**	1.604	3937.184

Accessibility									
Accessibility group 1 **Patients (body) with the highest accessibility** (5.275 or above) (Accessibility_body_1: access_cb_5_1)	16 (20.6)	27 (20.6)	-	-	-	-	-	-	-
Accessibility group 2 **Patients (body) with the second highest accessibility** (4.975 – 5.274999) (Accessibility_body_2: access_cb_5_2)	9 (11.5)	11 (8.4)	1.813	.963	3.546	**.060**	**6.130**	.929	40.464
Accessibility group 3 **Patients (body) with the middle range accessibility** (4.675 – 4.974999) (Accessibility_body_3: access_cb_5_3)	28 (35.9)	32 (24.4)	1.366	.665	4.224	**.040**	**3.921**	1.065	14.432
Accessibility group 4 **Patients (body) with the second least accessibility** (4.375 – 4.674999) (Accessibility_body_4: access_cb_5_4)	17 (21.8)	27 (20.6)	1.598	.901	3.144	**.076**	**4.943**	.845	28.914
Accessibility group 5 **Patients (body) with the least accessibility** (4.075 – 4.374999) (Accessibility_body_5: access_cb_5_5)	8 (10.3)	34 (26.0)	.120	.908	.017	.895	1.127	.190	6.679
Distance to Medication (mean)	622.03	623.97	-.002	.002	1.742	.187	.998	.995	1.001

Bathroom location (Headwall/footwall side)	7(9)/71(91.0)	16 (87.8)/115 (12.2)	-.732	.697	1.102	.294	.481	.123	1.885
Constant			-6.933	4.533	2.339	.126	.001		

6.6 Results of the Final Model (Sub-Group Analysis with Limited Collinear Variables) (Step 4)

6.6.1 Introduction

Incorporating the lessons-learned from previous analyses (from Steps 1, 2, and 3), the current study finalized the multivariate logistic model to be tested with the sub-group of data. Additional analyses from Step 3 identified three highly correlated variables (i.e., age, fall risk score, and Visibility I) from the original model. Age and fall risk score variables were highly correlated with all five fall-related patient characteristics (i.e., mobility, mentation, elimination, prior fall history, and medication) and Visibility I was highly correlated with Visibility II and Accessibility measures. In the final model, age and fall risk score variables were excluded, leaving all five fall-related patient characteristics that the variables were highly correlated. In addition, in the final model, the Visibility I variable was also excluded because it was highly correlated with the other two environmental variables (i.e., Visibility II and Accessibility) and because the investigator was not convinced that the Visibility I measure was meaningfully different from the Visibility II measure because data patterns across the two measures (Visibility I and II measures) were very similar. We might have been measured one variable in two different ways and, therefore, they might have been helping each other and produced biased results. This final model, in the end, was tested, without the Visibility I measure, with the sub-group (78 unassisted falls and 131 comparable non-fallers). The following section reports the results from testing the final model from Step 4. The comparison of the multivariate logistic regression equations (Step 1 versus Step 4) is as follows (bolded variables in the initial equation are the ones excluded from the final model):

Step 1 The initial Logistic Regression Equation

logit(p) = b + b1*(**age**) + b2*(gender) + b3*(length of stay at time of falling) + b4*(mobility) + b5*(mentation) + b6*(elimination) + b7*(history of falls) + b8*(current fall-related medication) + b9*(**fall risk score**) + b10*(**visibility I**) + b11*(visibility II) + b12*(accessibility) + b13*(distance to medication) + b14*(bathroom location in related to patient)

Step 4 The Final Logistic Regression Equation

logit(p) = b + b1*(gender) + b2*(length of stay at time of falling) + b3* (mobility) + b4*(mentation) + b5*(elimination) + b6*(history of falls) + b7*(current fall-related medication) + b8*(visibility II) + b9*(accessibility) + b10*(distance to medication) + b11*(bathroom location in related to patient)

6.6.2 Results (Step 4)

This final multivariate analysis (with limited collinear variables involving data from the 78 unassisted falls and their comparable non-fallers) identified several fall predictors associated with an increased risk of falling (See Table 6.20). These included ambulating with assistive device (mobility group 3), being periodically confused (mentation group 3), being always confused (mentation group 4), and not being visible from both the corridor and nurses' station (visibility II group 3). Some predictors originally identified as significant were no longer considered significant f. The moderate-visibility group, Visibility II, group 2 (patients not visible from a nurses' station but visible from corridor) was no longer associated with an increased risk of falling. At the same time, patient groups with less accessibility were no longer associated with an increased risk of falling in the final analysis.

6.6.2.1 <u>Significant Variables (or Predictors) Associated with Patient Falls</u>

1 Visibility II to patient

1.1 Compared to patients who were visible from both corridors and nurses' stations (high-visibility group - patient group 1), patients who were **not visible from the outside at all** (neither from the corridor or the nurses' station) (low-visibility group - the patient group 3) were much more likely to experience a fall ($p = .024$, one-tailed) controlling for all other variables in the model. The statistical findings, shown in Table 6.19, also demonstrated that the odds of falling were **3.75 times greater** for patients who were not visible from either the corridors or the nurses' stations (patient group 3) than patients who were visible from both corridors and nurses' stations (patient group 1), controlling for all other variables in the model. For the average patient (again, as determined by the mean values of all the model variables), the probability of experiencing a fall **increases 31%** when a patient is not visible at all from outside the room (from neither corridors nor nurses' stations) compared to a patient who is visible from both nurses' stations and corridors.

2 Mentation

2.1 Patients experiencing **periodic confusion** had a much higher probability of experiencing a fall ($p = .0005$, one-tailed) than those who were alert (patient group 1), controlling for all other variables in the model. The odds of falling were **5.72 times greater** for patients with periodic confusion (mentation patient group 3) than patients who were alert (mentation patient group 1). The probability of experiencing a fall **increased 40%** for patients with periodic confusion (mentation patient group 3) when compared to patients who were alert (mentation patient group 1).

2.2 Patients **always confused** had a higher probability of experiencing a fall (p = .048, one-tailed) than those who were alert (patient group 1), controlling for all other variables in the model. The odds of falling were **4.53 times greater** for patients with periodic confusion (mentation patient group 3) than patients who were alert (mentation patient group 1). The probability of experiencing a fall **increased 36%** for patients with periodic confusion (mentation patient group 3) when compared to patients who were alert (mentation patient group 1).

3 Mobility

3.1 Patients **ambulating with an assistive device** (patient group 3) had a higher probability of experiencing a fall (p = .036, one-tailed) than those ambulating without problems (patient group 1), controlling for all other variables in the model. The odds of falling were almost **2.43 times greater** for patients ambulating with an assistive device (the mobility patient group 3) than patients ambulating without problems (the mobility patient group 1). The probability of experiencing a fall **increased 20%** for patients ambulating with an assistive device when compared to patients who ambulating without problems.

Table 6.20 The Outcome of the **Final Analysis Step 4** (with Limited Collinear Variables and Only 78 Unassisted Inpatient Falls): Multivariate Model of Environmental and Fall-related Patient Factors Associated with Falling in the Hospital

Factor	Falls *N =78* (%)	Controls *N =131* (%)	B	S.E.	Wald	Sig.	aOR	95% C.I.for EXP(B)	
								Lower	Upper
Patient characteristics									
Gender(M/F)	37 (47.4)/41 (52.6)	51 (38.9)/80 (61.1)	-.337	.354	.907	.341	.714	.356	1.429
LOS at time of falling (mean)	4.16	3.22	.108	.073	2.164	.141	1.114	.965	1.286
Mobility									
Ambulate without problems	16 (20.5)	41 (31.3)							
Unable to ambulate	3 (3.8)	10 (7.6)	-1.459	1.133	1.659	.198	.232	.025	2.140
Ambulate with assistive device	27 (34.6)	40 (30.5)	.887	.521	2.899	**.089**	**2.427**	.875	6.738
Ambulate unsteadily	32 (41.0)	40 (30.5)	.517	.568	.829	.363	1.677	.551	5.102
Mentation									
Alert	51 (65.4)	110 (84.0)							
Unresponsive	0 (0)	1 (.8)	-16.667	40192.970	.000	1.000	.000	.000	.
Periodic confusion	23 (29.5)	14 (10.7)	1.744	.532	10.730	**.001**	**5.719**	2.015	16.237
Always confused	4 (5.1)	6 (4.6)	1.510	.903	2.796	**.095**	**4.528**	.771	26.588
Elimination									
Independent	20 (25.6)	37 (28.2)							
Independent with frequency	5 (6.4)	5 (3.8)	.785	.864	.825	.364	2.192	.403	11.915
Needs assistance	46 (59.0)	79 (60.3)	-.376	.491	.585	.444	.687	.262	1.798
Incontinent	7 (9.0)	10 (7.6)	.549	.903	.369	.544	1.731	.295	10.169
Prior fall history									
No	41 (52.6)	74 (56.5)							
Unknown	18 (23.1)	23 (17.6)	-.594	.502	1.401	.237	.552	.206	1.477
Yes before admission	19 (24.4)	34 (26.0)	-.732	.467	2.452	.117	.481	.192	1.202
Current fall-related medication									
None	58 (74.4)	91 (69.5)							
Anti-convulsant	1 (1.3)	1 (.8)	1.985	1.569	1.601	.206	7.280	.336	157.579
Tranquilizers	2 (2.6)	5 (3.8)	-.369	1.140	.105	.746	.691	.074	6.455
Psychotropics	9 (11.5)	12 (9.2)	-.122	.585	.043	.835	.885	.281	2.788
Hypnotics	8 (10.3)	22 (16.8)	-.579	.517	1.252	.263	.561	.203	1.545

Environmental factors

Visibility2

Visibility2 group1: **High-visibility group** Patients (heads) who are visible from both nurses' stations and corridors (visibility2_h210_1)	19 (24.4)	38 (29.0)	-	-	-	-	-	-	-
Visibility group 2" **Moderate-visibility group** **Patients (heads) who are visible only from only corridors (not visible from nurses' station)** (visibility2_h210_2)	39 (50.0)	71 (54.2)	.483	.469	1.059	.303	1.621	.646	4.065
Visibility group 3 **Low-visibility group** **Patients (heads) who are NOT visible at all from outside** (both a nearby nurses' station and a corridor (visibility2_h210_3)	20 (25.6)	22 (16.82)	1.320	.668	3.907	**.048**	**3.744**	1.011	13.861

Accessibility									
Accessibility group 1 Patients (body) with the highest accessibility (5.275 or above) (Accessibility_body_1: access_cb_5_1)	16 (20.6)	27 (20.6)	-	-	-	-	-	-	-
Accessibility group 2 Patients (body) with the second highest accessibility (4.975 – 5.274999) (Accessibility_body_2: access_cb_5_2)	9 (11.5)	11 (8.4)	.837	.747	1.254	.263	2.309	.534	9.986
Accessibility group 3 Patients (body) with the middle range accessibility (4.675 – 4.974999) (Accessibility_body_3: access_cb_5_3)	28 (35.9)	32 (24.4)	.851	.561	2.296	.130	2.341	.779	7.034
Accessibility group 4 Patients (body) with the second least accessibility (4.375 – 4.674999) (Accessibility_body_4: access_cb_5_4)	17 (21.8)	27 (20.6)	.552	.630	.768	.381	1.737	.505	5.977
Accessibility group 5 Patients (body) with the least accessibility (4.075 – 4.374999) (Accessibility_body_5: access_cb_5_5)	8 (10.3)	34 (26.0)	-.906	.662	1.873	.171	.404	.111	1.479
Distance to Medication (mean)	622.03	623.97	-.513	.653	.618	.432	.598	.166	2.153
Bathroom Location (Headwall/footwall side)	7(9)/71(91.0)	16 (87.8)/115 (12.2)	-.001	.001	.180	.671	.999	.997	1.002

CHAPTER 7

DISCUSSION AND CONCLUSIONS

7.1 Introduction

This study demonstrates that certain environmental factors are associated with an increased risk of falling. Whether or not a patient's head area is visible from a nearby decentralized nurses' station and whether a patient's head area is visible from corridors are all important factors in predicting the incidence of falls. The measures are not, of course, the reasons for falls, but rather they suggest that hospital staff are less likely or able to intervene on a patient's behalf before the fall occurs if that patients is less visible. The study recognizes the role of better visibility in promoting organizational functioning, particularly in surveillance, peer and situation awareness, and timeliness and, in turn, in preventing patient falls. This section discusses and analyzes results of the final analysis (Multivariate Logistic Regression: Step 4).

The current study demonstrated that visibility contributes to patient falls and less visibility to a patient increases the risk of falling. The low-visibility patient group had a significantly higher risk of falling compared to the high-visibility patient group. If we revisit the operationalized definitions of different visibility groups, this means that patients NOT visible from both a nearby decentralized nurses' station (from designated seats with 210 normal visual angles) and a corridor (with a normal walking pattern) [**low-visibility group**] had a significantly higher risk of falling, compared to patients visible from both a nearby decentralized nurses' station and a corridor [**high-visibility group**].

The study demonstrates that better visibility contributes to patient safety through its role in reducing patient falls. Emerging evidence also supports this finding as establishing the direct association between visibility and patient-related outcomes (i.e., patient falls and mortality rates) (Hendrich, Fay, & Sorrells, 2004; Leaf, Homel, & Factor, 2010; Vassallo, Azeem, Pirwani, Sharma, & Allen, 2000) (See Figure 5.4). The study also aimed to promote a better understanding of physical environmental or design factors in improving organizational functioning, particularly in surveillance, peer and situation awareness, and timeliness (See Figure 5.3).

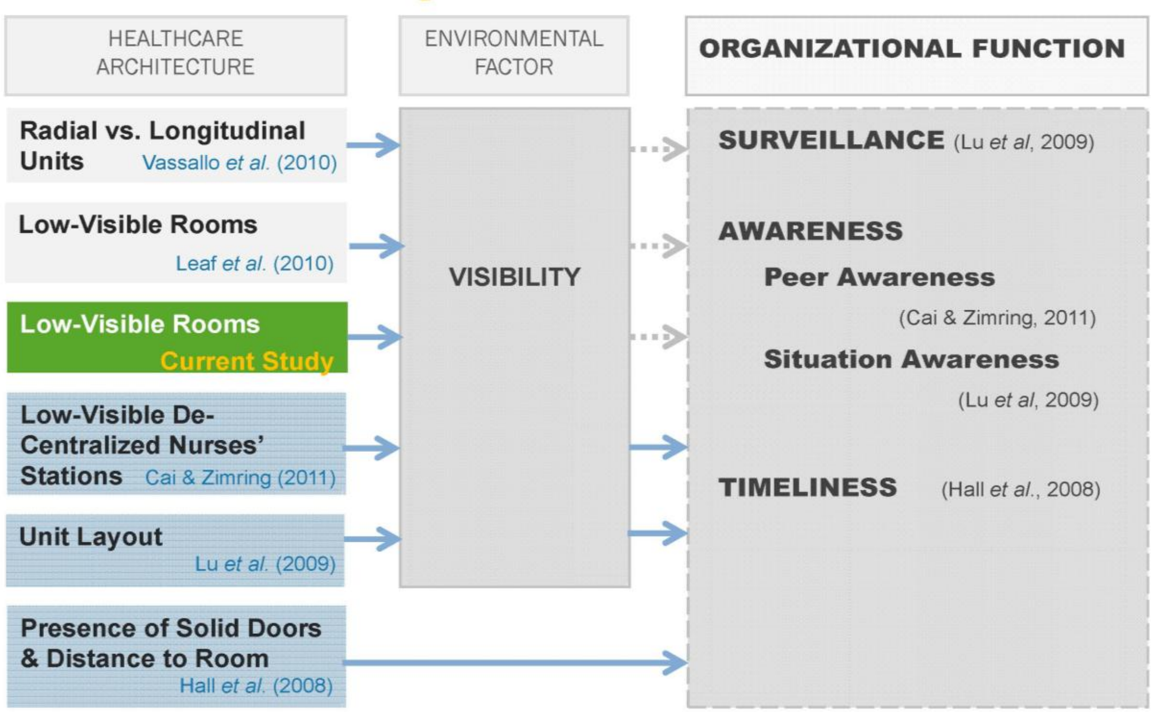


Figure 5.3 Healthcare Architecture, Visibility, and Organizational Function

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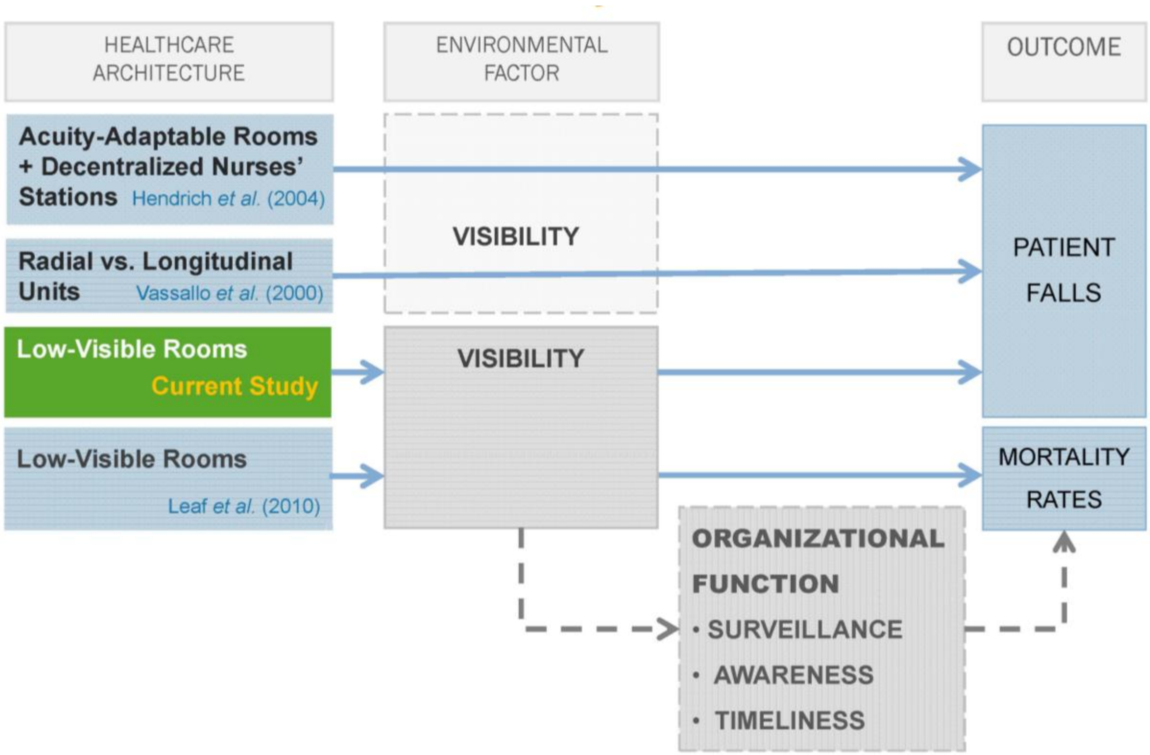

Figure 5.4 Healthcare Architecture, Visibility, and Patient Safety

This figure is brought to this chapter again for emphasis.

7.2 Comparison between Hypotheses and Findings

7.2.1 Visibility I

Two general models of patient visibility were employed in this study. The hypothesis of the first model, Visibility I, was as follows: the smaller the spatial area in which a patient is visible within the unit, the greater the probability of falling for the patient. Having less spatial area in which the patients are visible may be associated with a reduced opportunity for caregivers to maintain visual access to or surveillance of patients and, therefore, it may reduce caregivers' ability to intervene in situations where a fall appears likely to occur.

As mentioned in section 6.3.8.1, none of the measures in the Visibility I model were significantly associated with inpatient falls. This demonstrated that the magnitude of the area in which a patient is visible within a unit is not a significant predictor for inpatient falls.

7.2.2 Visibility II

The hypothesis of the second visibility model, Visibility II, was as follows: patients who are not visible from both a nearby decentralized nurses' station and a corridor (low-visibility group) will have greater probability of falling than those visible from both a nearby decentralized nurses' station and also a corridor (high-visibility group). This model is different from the first visibility model (Visibility I) to the extent that this model takes into account the functional aspects of the area in which a patient is visible.

One of Visibility II measures (low-visibility) was identified as a significant predictor to inpatient falls. It is important to note that those significant Visibility II measures all concern the visual access from designated seats in a nearby decentralized nurses' station (with 210 degree visual angles from the seats). In other words, being visible from designated seats in a nearby decentralized nurses' station (with 210 visual angles from the seats) was significantly associated with a decreased risk of falling.

Depending on where a patient room is located in relation to key functional spaces such as decentralized nurses' stations, a patient has a varying level of visibility compared to other patients in the same unit. As shown in Figure 5.8, some patient rooms offer almost complete visibility to patients' heads or bodies from the seats at decentralized nurses' stations (assuming a 210 degree visual angle from the seats) as opposed to other rooms that offer no visual access to patients' heads. The study did not identify a significant increase in the risk of falling for patients whose heads were visible only from corridors (moderate-visibility group) compared to patient whose heads were visible from both a nearby decentralized nurses' station and a corridor (high-visibility group). Furthermore, as shown in Figure 5.9, some patient rooms do not even offer visual access to the patient's head from adjacent corridors, at least when considering a normal pattern of walking through the corridors. This means that patients in those rooms will not be visible to any caregivers in the unit unless the caregivers intentionally alter their walking routes to check in on the patient. The findings showed that patients in those rooms (or patients whose heads are not visible at all from adjacent corridors and nearby nurses' stations) (low-visibility group) have **3.75 times greater** odds of falling when compared to patients in rooms that are visible from nurses' stations (high-visible group) (Figure 5.10).

In summary, there was the striking finding that patients who were **not visible from the outside at all** (neither from the corridor nor the nurses' station) **[low-visibility group]** had a much higher chance of experiencing a fall ($p = .012$, one-tailed) than those who were visible from both corridors and nurses' stations **[high-visibility group]**, controlling for all other variables in the model (Figure 7.3). The odds of falling were **3.75 times greater** for low-visibility patient group than high-visibility patient group, controlling for all other variables in the model. The probability of experiencing a fall **increases 31%** when a patient is not visible at all from outside the room (from neither corridors nor nurses' stations) compared to a patient who is visible from both nurses' stations and corridors.

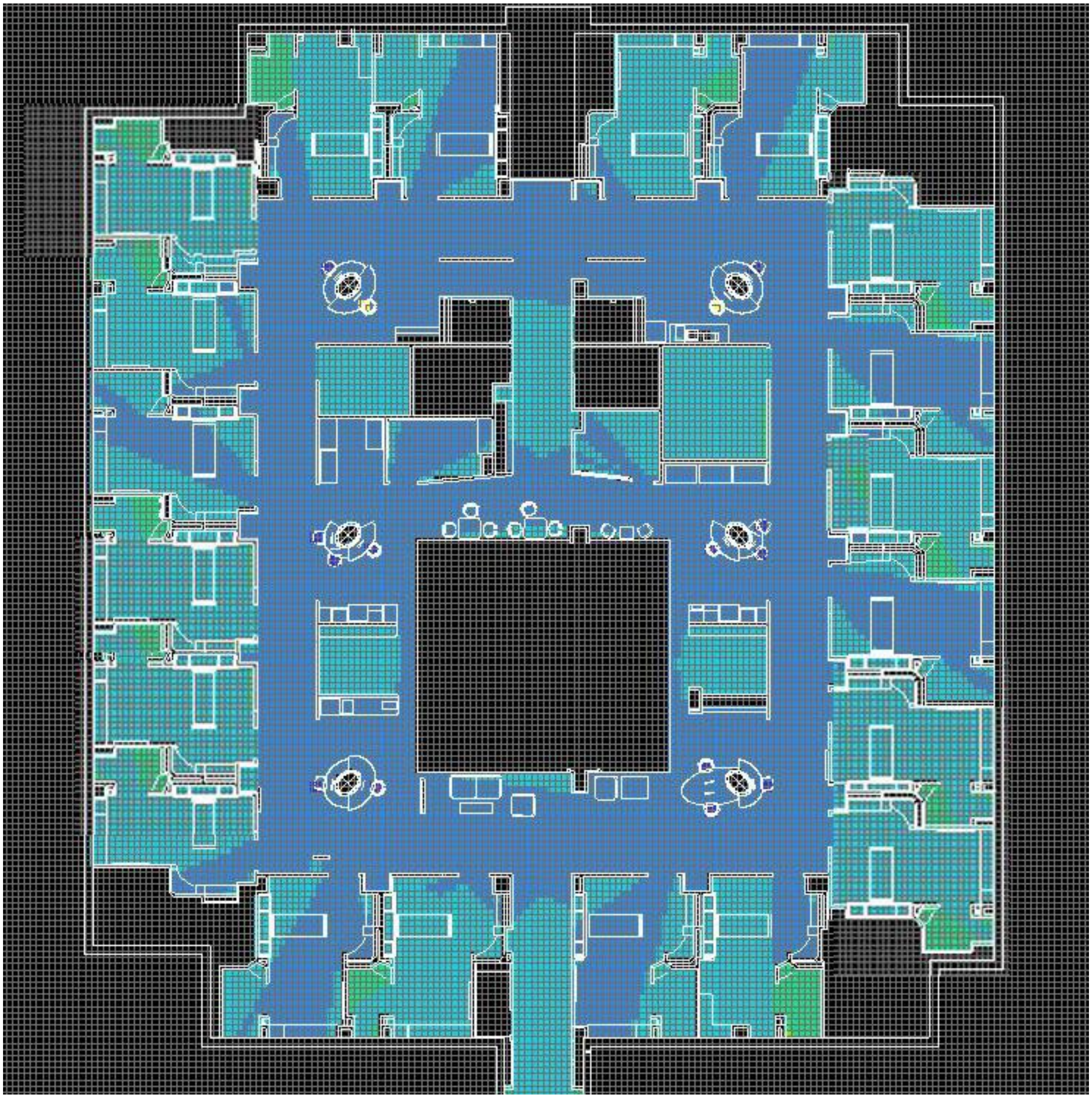

Figure 5.8 Analysis of Patient Visibility from Designated Seats at Nurses' stations (with a 210 Degree Visual Angle and with Seats Oriented for a Normal Pattern of Use). Spaces in Blue are Visible from the Seats.

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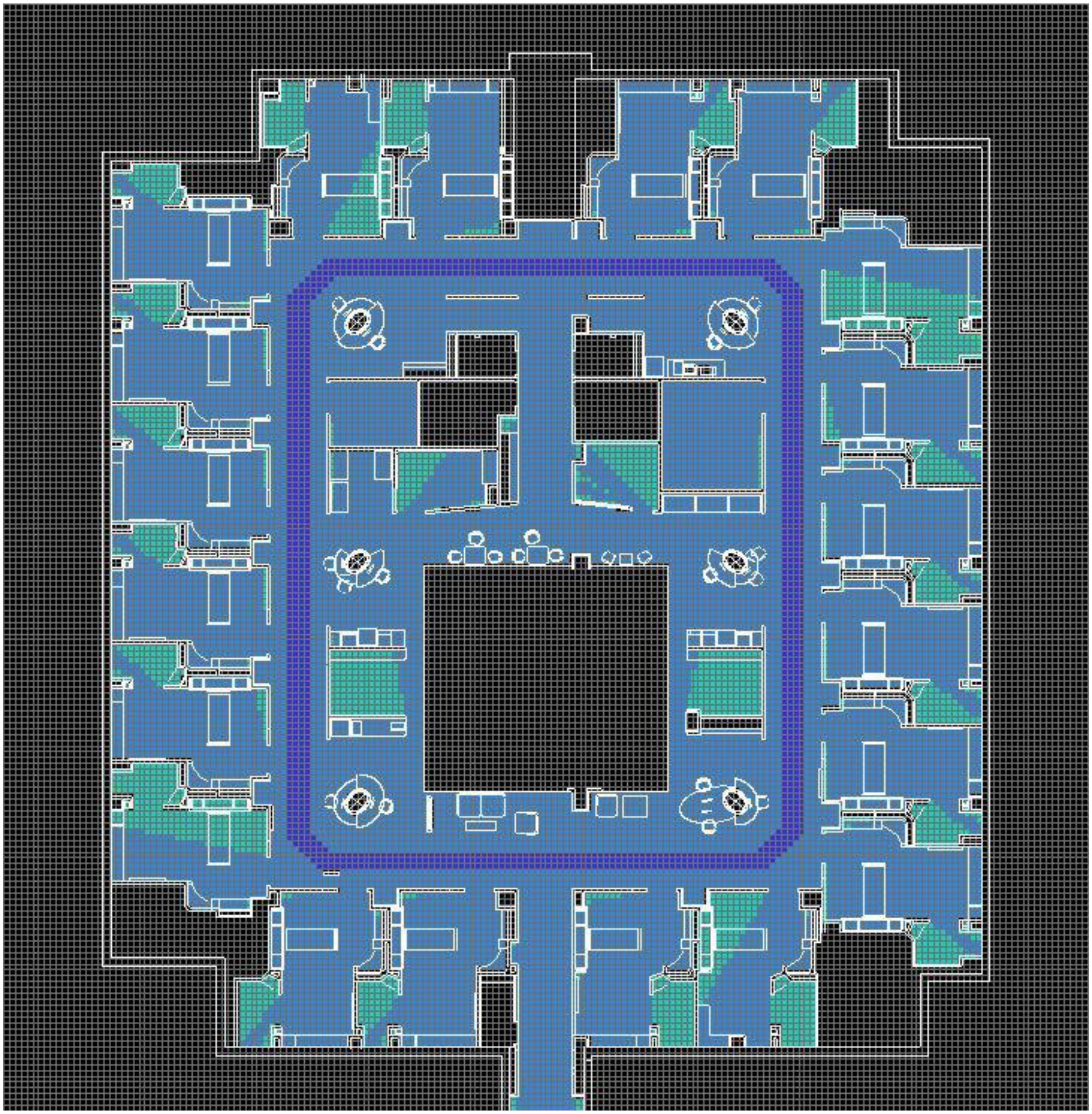

Figure 5.9 Analysis of Patient Visibility from Corridors, Considering a Normal Route of Walking. Dark Blue Indicates the Walking Path. Light blue Indicates Areas Visible from the Walking Path.

The figure is brought to this chapter again for emphasis.

High-Visible Room

- Patients in the rooms are visible from a nearby nurses’ station

Moderate-Visible Room

- Patients in the rooms are visible only from corridor

Low-Visible Room

- Patients in the rooms are NOT visible from corridor

Figure 5.10 Three Patient Room Groups in Visibility II measure

The figure is brought to this chapter again for emphasis.

7.2.3 Accessibility to Patient

The hypothesis related to patient accessibility was as follows: the least accessible patients have a greater probability of falling than those who are highly accessible. In other words, a patient in the area that is least accessible from any other part of the unit will have a greater probability of falling. Being segregated or being less accessible may be associated with having fewer caregivers in the immediate area who can respond to the patient in a timely manner in situations where a fall appears likely to occur. This hypothesis was not supported by findings. Multivariate analyses led to the conclusion that the variable (accessibility to patient) was not significant factors associated with patient falls, controlling for all the other factors in the model.

7.2.4 Distance to Medication and Bathroom Location

The hypothesis related to distance to medication was as follows: patients far from medication areas have a greater probability of falling than those close to a medication area. The locations of certain functional spaces like the medication area have an effect on where caregivers tend to spend their time. Of course, this is in addition to the overall layout of the unit, which determines the overall pattern of caregivers' presence in the unit and the relative accessibility of each patient. Therefore, the distance to the functional space (i.e., the medication area), which was identified as the busiest area on unit, does matter. Patients who are far from a medication area will be subject to less visual surveillance and less proximity to caregivers, and thus reduced opportunities for caregivers to intervene in situations where a fall appears likely to occur.

The hypothesis related to bathroom location was as follows: patients whose bathroom is located on the footwall side of the room will have a greater probability of falling than those whose bathroom is located on the headwall side. Having the bathroom located on the footwall side will increase the distance a patient must walk without a handrail support. Healthcare design experts suggest that a bathroom on the headwall side may be associated with a reduction in patient falls for several reasons: being on the same wall potentially reduces the distance from the patient bed to the bathroom and makes it easier to install continuous handrails from the bed to the bathroom door.

Multivariate analyses led to the conclusion that two variables (distance to medication and bathroom location) were not significant factors associated with patient falls, controlling for all the other factors in the model. However, it is important to note that significant relationships between the environmental variables (visibility and accessibility to patients) and inpatient falls were only apparent when the analyses included those two specific variables (distance to medication and bathroom location) in the model. This indicates that even though those variables were not statistically significant factors associated with patient falls in this study, they certainly play a role, and therefore the analyses revealed the impact of other significant environmental factors. Even though the impacts of those variables were not strong enough to be statistically recognizable in this study, future studies must investigate their association with patient falls.

7.2.5 Collaborative Impact of All Environmental Variables of Interest

The final hypothesis of this study was as follows: all the environmental factors listed above play their roles simultaneously. Therefore, it is important to test the impact of each variable when incorporating (or controlling for) the impact of the other environmental variables. One hypothesis states that being visible from a nearby decentralized nurses' station (Visibility II) would be a dominant factor associated with patient falls, which means that the factor will remain significant when considering the impact of other environmental factors including distance to medication and bathroom locations.

This hypothesis was supported by the findings. Being visible from a nearby decentralized nurses' station (Visibility II), especially from designated seats and allowing what is considered a realistic visual angle of210 degrees from a given point, was the most significant factor associated with a decrease in the probability of experiencing a fall. In other words, not being visible from a nearby decentralized nurses' station (Visibility II) is a significant predictor of patient falls. More detailed explanations of the findings were presented in the earlier part of this section.

7.3 Design Implications

It should be emphasized that the physical environmental factor (visibility to patient) associated with fall risk is determined by the unit and room layouts. Therefore, fall risk can be reduced by improving the design of units and patient rooms. The following section discusses how the analysis of environmental fall risk factors can inform future designs and how falls can be mitigated by good design.

7.3.1 Visibility from Designated Seats at Nurses' Stations to Patients' Heads

This study tested several sub-measures of visibility to identify which visibility measure matters most when it comes to predicting patient falls. Importantly, the findings stemming from this research could also inform facility design. After testing a series of statistical models with different combinations of visibility measures, we identified that the following sub-measures of visibility better explained the relationship between visibility and inpatient falls by creating better fitting statistical models. They are the following: 1) measures based on whether or not a patient's head is visible, 2) measures taken from designated seats in nurses' stations, and 3) measures from designated seats in nurse' stations, where we took into account the normal visual angle from the seats, as well as the direction the seats faced.

The findings demonstrated that the visibility of a patient's head matters a great deal and is much more significantly associated with inpatient falls than the visibility of any other part of a patient's body. In addition, it is critical to have visual access to a patient's head directly from the designated seats in a nurses' station, with a normal visual pattern of 210 degrees from a given seat, and a normal pattern of orientation for the seats. These findings could be used directly to shape and guide the design of a unit and/or a patient room. It suggests that a patient room layout needs to be designed to increase the visibility of the patient's head, especially directly from the seats in a nearby decentralized nurses' station and considering the way the station is used and the normal visual angle from those seats. It is also recommended to lay out nurses' stations to provide more seats from which staff can easily establish direct lines of sight to patients' heads.

7.3.2 Design Suggestions To Improve Patient Visibility From Nurses' Stations

In the planning stages for inpatient units and the rooms within them, it is recommended that designers assess visibility to each patient's head when the patient is in the room. Using the findings of that assessment, designers should fine-tune the layout of the unit and the patient rooms to maximize the visibility of patients' heads. Within the scope of the unit layout, the location and orientation of a patient room in relation to nearby nurses' stations and/or the locations of nurses' stations should be adjusted to create better visibility. As an example, Figure 7.1 illustrates how the different orientations of a patient room can create different levels of patient visibility. Although the patient rooms in Figure 7.1 are exactly same in layout, the orientation of the ones on the left side is mirrored 180 degrees compared to the rooms on the right. Even though they are also nearly identical in their relation to the locations of nearby nurses' stations, the rooms on the left side differ in their level of patient visibility due to their different orientations compared to the rooms on right side. In the scope of the patient room layout, the locations of doors and patient beds or materials on the corridor side wall could be manipulated to create better visibility to patient's heads. For example, Figure 7.2 illustrates how various door openings locations relative to the orientation of patient beds (or headwalls) can make a difference in the visibility of patients' beds. With the adjustments in locations of door openings and patient beds, visual access to patients' heads could be improved in all four rooms.

The examples provided here might lead to a debate about the pros and cons of same-handed or mirrored room designs because, in the first example (Figure 7.1), rooms were laid out to be same-handed, while in the second example (Figure 7.2), the rooms were mirrored. The defining difference between mirror-image and same-handed rooms is the positioning of the headwall of a patient's bed. Standardized mirror-image rooms share the wall that accommodates their headwalls, so they are reflections—back-to-back mirror images of each other. The headwalls in same-handed rooms do not share a wall. They are always positioned on the same side of the patient room, typically the left sidewall, which encourages an approaching caregiver to be positioned on the patient's right. Although the mirrored room design was once common because of its cost-effectiveness (sharing bathroom plumbing chases in mirrored rooms cuts the construction costs significantly), research evidence started to suggest that same-handed rooms may cause fewer errors because of their standardization (Cahnman, 2006; Watkins, Kennedy, Ducharme, & Padula, 2011). Same-handed design is also seen as facilitating a consistent approach to the right side of a patient, which has been advanced as the optimum caregiver location. With the standardization of approach and location *vis-à-vis* the patient, elements in the environment can be designed and located to provide caregivers with familiar settings that reduce their cognitive burden and lead to safer patient-care support (Shraiky & Schoonover, 2010). Even though the issues surrounding same-handed and mirrored rooms are worthy of further discussion, the focus of this study was elsewhere. Therefore, the examples are only for a demonstration of how patient visibility can be different depending on the locations of patient beds and door openings; it is not meant as a recommendation of mirrored rooms over identically laid-out rooms.

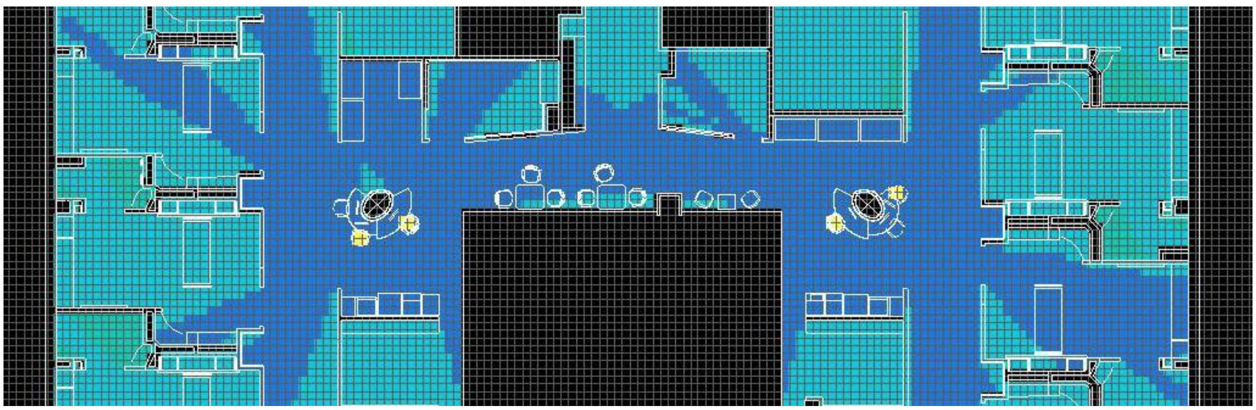

Figure 7.1 Analysis of Visibility to Patients' Heads In the Dublin Inpatient Unit as Currently Designed (Visible Areas are Dark Blue)

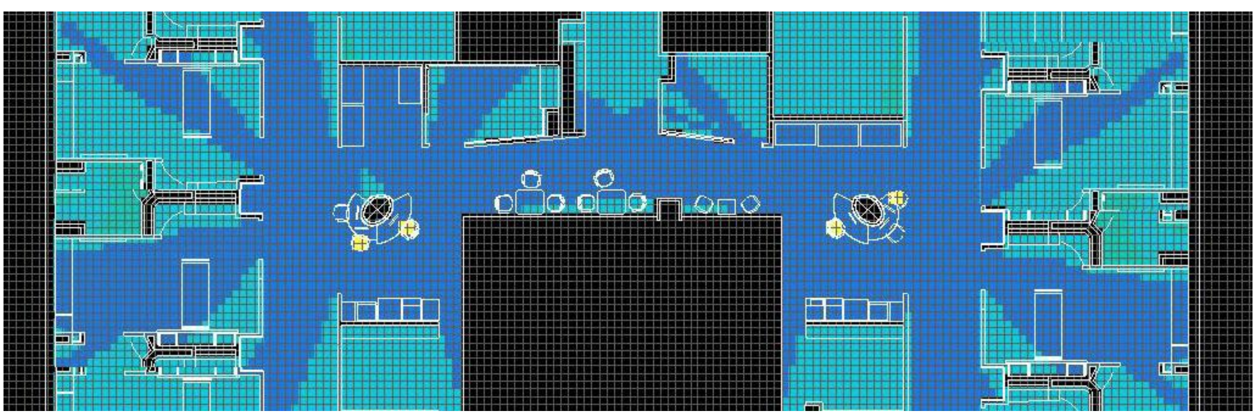

Figure 7.2 Improved Visibility to Patients' Heads with Adjusted Locations for Patient Beds and Door Openings

7.3.3 Design Suggestions to Improve Patient Visibility from Corridors

The visibility analysis of the Dublin inpatient unit showed that some patients are not visible even from corridors, unless staff changed their normal walking patterns (See Figure 5.9). These rooms with no visibility are located in the corners of the unit, presenting special challenges in maintaining visibility from the rest of the unit. Furthermore, the findings of the multivariate regression analyses demonstrated that patients in those rooms have **3.74 times** greater odds of falling when compared to patients in rooms visible from nurses' stations. Therefore, it is important that designers are aware of the risk associated with such rooms and take necessary measures to prevent creating such rooms within a unit. The same design strategies suggested in the sections above, such as assessing visibility and fine-tuning patient room and unit layouts, locations of patient beds and door openings, and materials on corridor side walls, can be applied here as well to increase patient visibility from corridors. As an example, Figure 7.3 shows a dramatic difference in visibility to patients' head areas between two corner rooms (patient rooms 3208 and 3213). Even though those two rooms are both located in corners of the unit, they offer completely different levels of visibility to patient's head areas: room 3213 offers a complete visual access to a patient's head from the corridor as opposed to room 3208, which does not offer visual access to a patient's head area at all from the corridor. The design factor that causes such differences in this case is the location of the headwall. In terms of unit layout, the location of the patient room can be also altered to improve the visibility to patients. Figure 7.4 shows improved visibility to a patient's head area from the corridor when the location of the room within the unit is slightly changed. With this small modification of the room location, it now offers complete visual access to a patient's head area as shown in the picture on the right hand side.

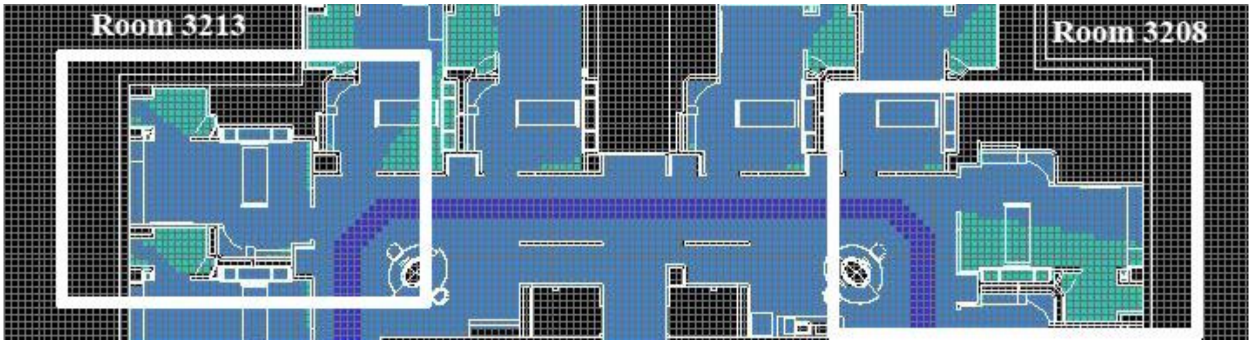

Figure 7.3 Dramatic Difference in Visibly to Patients' Head Areas between Two Corner Rooms (Patient Rooms 3213 and 3208): Light Blue Areas Indicate the Area Visible from the Corridor Circulation (the Dark Blue Areas), Corresponding Normal Staff Walking Patterns.

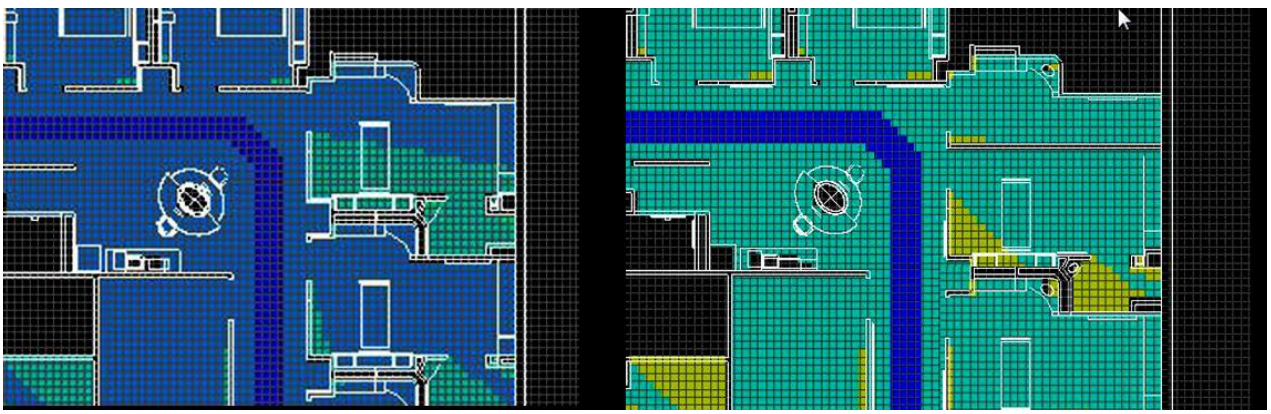

Figure 7.4 Improved Visibility to a Patient's Head area from the Corridor with a Slight Change in the Patient Room Location: The Light Blue (on the Left Figure) and Turquoise (on Right Figure) Areas Indicate the Areas Visible from the Corridor Circulation (the Dark Blue Areas)

7.4 Strengths, Limitations, and Future Research Directions

The strengths of this study include the fact that it is one of the first attempts in the field to establish direct associations between physical environmental factors and a clinical outcome (i.e., inpatient falls). This study benefitted from an outstanding opportunity to access clinical data on inpatient falls and, therefore, the identification of precise inpatient fall locations (i.e., patient room numbers and where falls occurred within those rooms). Second, the study investigated various fall-related patient characteristics that may affect the outcomes of inpatient falls and, by statistically controlling the impact of all the patient variables , the study found the significant associations between certain physical environmental factors and inpatient falls that can be solely attributable to those environmental factors. Third, this study made contributions to both substantive and methodological areas. It investigated the effects of the unit and room layout-related environmental factors, which have not been studied previously, on the outcome of inpatient falls in hospital settings. . Further, the study developed operational measures of the unit and room layout-related physical environmental factors that may be associated with inpatient falls and demonstrated the association of some key physical environmental factors with inpatient falls.

One limitation of the current study is that, as one of the first attempts to establish direct associations between physical environmental factors and inpatient falls, the findings of the study must be confirmed by future studies. Secondly, because the dependent variable is a relatively rare event, the sample size was relatively small (209 samples in the sub-group analysis and 236 in the total group analysis) even though it included a three-year data. The sample size of the study was slightly less than the estimation (248 samples) of power analysis but still future studies can benefit from the larger sample size. Third, in quasi-experimental studies, the groups compared can be different because of lack of randomization (Cepeda, 2003). Subjects with specific characteristics may have been more likely to be exposed to the treatment of interest than other subjects. The current study utilized logistic regression, a commonly used method, to control for the possible imbalances between groups. Its primary advantage is the ability to control for many variables simultaneously (Cepeda, 2003). However, there was a concern that, if too many variables need to be included in a model relative to the number of events, the estimates from logistic regression models can be incorrect (Harrell, 1984; Peduzzi, 1996). Therefore, the current study that includes the relative high number of variables (26 variables) could benefit from another methodological approach – the propensity score, which is the conditional probability of a subject's receiving a particular exposure given the set of confounders to control for imbalances between groups. For calculation of a propensity score, the confounders are used in a logistic regression to predict the exposure of interest, without including the outcome (Rosenbaum, 1983, 1984). As a result, the collection of confounders is collapsed into a "single" variable, the probability (propensity) of being exposed (Cepeda, 2003). Creating a covariate that summarizes all the confounders could circumvent the problem of having too many variables in the model relative to the number of events. Therefore, future studies with rare events (outcomes) and multiple confounders should recognize benefits of the propensity score and may apply the method when selecting control groups.

7.5 Conclusions

This study applied several hypotheses about the relationships between environmental factors and patient falls in hospital facilities. Facility and patient data were gathered from the private facility Dublin Methodist Hospital in Dublin, Ohio. The data included information about patients who fell, as well as patients with similar profiles who did not fall, with the latter acting as comparison cases. The physical environmental factors tested in this study included visibility to the patient, accessibility to the patient, distance from the medication room to the patient, and bathroom location in relation to patient.

The first and second hypotheses stated, respectively, that if there is less spatial area in which a patient is visible within a unit, the greater the odds of falling for the patient, and that patients who are not visible from a nurses' station, or visible only from a corridor, or not visible from anywhere within a unit will have greater odds of falling than those visible from a nearby decentralized nurses' station. Analysis of fall and facility data showed that the magnitude of the area (Visibility I) in which a patient is visible within a unit is not a significant predictor for inpatient falls. On the other hand, whether or not a patient is visible from a nearby decentralized nurses' station or corridors (Visibility II) was a significant predictor to inpatient falls. In particular, Visibility II measures concerning the visual access from designated seats in a nearby decentralized nurses' station (with the expected orientation of seating and assuming 210 degree visual angles from the seats) were significant predictors for inpatient falls. In other words, being easily visible from designated seats in a nearby decentralized nurses' station was significantly associated with a decreased risk of falling.

Analysis of fall and facility data also showed the part of the body (e.g. any part, or the torso, or head) that was visible to staff outside the room had a relationship to the likelihood of a fall. Further, the specific location(s) from which those body parts were visible proved very important. In the end, the Dublin data showed that visibility (or lack of visibility) of the patient's head area from nurses seated at a nurses' station was highly correlated to the incidence of falls. In those rooms with the poorest measured visibility, where patients' heads were not visible even from the corridor directly outside their room, patients were **3.74 times** more likely to fall as compared to patients who were visible from a nurses' station. When it is converted to the probability of falling, the probability of experiencing a fall **increases 31%** when a patient is not visible at all from outside the room (from neither corridors nor nurses' stations) compared to a patient who is visible from both nurses' stations and corridors.

The third hypothesis was that the least accessible patients have greater odds of falling than those who are highly accessible. Software ("Depthmap") was used to create quantified measures of patient accessibility for individual patient rooms. There was some benefit in terms of reduced odds of falling that stemmed from higher levels of accessibility but none of associations were statistically significant. Curiously, the odds of falling for patients with the least accessibility had less odds of falling than those with the highest accessibility. Due to the in consistent and counterintuitive patterns in the results associated with accessibility, the association between accessibility and patient falls is inclusive.

The fourth hypothesis stated that patients far from a medication area have greater odds of falling than those close to a medication area. Direct measurements of the distance from a medication station to the head of faller/non faller patients in their rooms were obtained. The analysis concluded that this distance was not by itself a statistically significant predictor to patient falls but we need to acknowledge its possible impact on patient falls. This finding should be validated by future studies.

Something similar was true regarding the fifth hypothesis, which stated that patients whose bathrooms are located on the footwall side of their room will have greater odds of falling than those whose bathrooms are located on the headwall side. Again, when other variables were controlled for, bathroom location was not statistically significant as a fall predictor, but should still be considered in future studies.

The most striking conclusion was that for a number of reasons, more patients fell when their heads were not visible to nurses working from their seats in nurses' stations and/or from corridors. The implications for hospital design are clear: design patient areas so that patients (especially their heads) are maximally visible from nurses' stations and corridors. Many hospitals can benefit from these findings by including guidelines and procedures for assuring visibility in their inpatient units. These findings can be further confirmed by follow-up studies with larger sample sizes.

APPENDIX A

FALL PREVENTION POLICY AT DUBLIN METHODIST HOSPITAL

Dublin Methodist Hospital OhioHealth	STANDARD POLICY and / or PROCEDURE	
	TITLE: *Fall Prevention*	NUMBER: *PC-13-DBHSP*
	ISSUED: 1/7/08	EFFECTIVE: 1/7/08
	REVISED: 2/28/09	
	DISTRIBUTION: All SPP Holders	
	DEVELOPED BY: Nursing Leadership	
	REVIEWED BY: Chief Nursing Officer	DATE: February 28, 2009
	APPROVED BY: Medical Executive Committee	

SCOPE: This policy is effect for Dublin Methodist Hospital (DMH).

STATEMENT OF PURPOSE:
Hospital Staff will engage in fall prevention activities for the purpose of reducing the occurrence and/or the severity of patient falls.

DEFINITIONS:
FALL: Any event which results in the patient or a body part of the patient coming to rest inadvertently on the ground or other surface lower than that of the patient.

POLICY:
All patients (excluding newborns) will be assessed for risk of falling after admission to the hospital. Interventions will be instituted for those patients identified at risk for experiencing a fall. Surgical and endoscopy patients are considered to be at risk for falls due to sedation and anesthesia.

Patients who are identified at "risk for falls" will be communicated to all staff providing care for the patient.

PROCEDURE:
Assessment
1. Upon admission, every patient will be assessed by the Registered Nurse for Fall Risk using the Fall Risk Assessment tool on the appropriate Nursing Daily Flow Sheet.
2. Data about the patient's Fall Risk may be collected by unlicensed or licensed providers. This data will be communicated to the Registered Nurse.
3. With initial am and pm assessments, and as needed, patients will be reassessed for Fall Risk using the Fall Risk Assessment tool on the appropriate Nursing Daily Flow Sheet. Exception: maternity patients will be assessed upon admission, then with any change in condition.
4. Any patient who receives a score of three (3) or higher on the Fall Risk Assessment is determined to be at risk for Falls. The Registered Nurse will institute an individualized Plan of Care for prevention of Fall.

Care of the Patient
The following interventions are recommended for use by patient care staff, as appropriate, to prevent patient falls.

For all Patients:
1. Orient patient to person, place, time, and environment, physical set-up of room and use of call light. Reorient patient as needed.
2. Provide clear instructions regarding mobility restrictions, proper ambulation and transfer techniques.
3. The environment should be maintained for safety:
4. The normally used pathways in the patient's room will be free of clutter which may pose obstacles to safe ambulation (IV poles, over bed tables).
5. The floors will be clean and dry – spills will be cleaned immediately.
6. The patient will have ready access to equipment needed for toileting (urinal within reach, bedside commode in position).
7. Bed and equipment locked.
8. Necessary objects will be in easy reach of patient (call light, over bed table with water pitcher).
9. Adequate lighting will be maintained.
10. Patients should wear non-skid footwear at all times unless contraindicated.
11. Staff should provide for toileting of patients at regular intervals, especially at bedtime.
12. Bed height will be maintained in the lowest position at all times except when care is being delivered.
13. Side rails may be used to assist the patient with positioning. Upper side rails only should be used for this purpose. Side rails are never used to prevent the patient from exiting the bed.

For patients at risk:

1. Place visual identifier on the patient's medical record to communicate the risk for falls; place fall magnet in patient's room or on door frame.
2. Visual reminder to ask for assistance will be posted at the bedside in the patient's line of vision.
3. Encourage visiting family members to provide companionship, call for help or assist with ambulation and follow interventions to prevent falls.
4. Staff will observe patient at risk for falls at least every 2 hours.
5. Implement individualized interventions, based on the reason the patient is at risk for falls:
   - Confused/altered mental status (e.g. Consider pharmacy consult for medication evaluation, low bed, bed alarm, diversional activities, move patient closer to station)
   - Altered mobility (e.g. Request consult for PT/OT; stay with patient during toileting)
   - Altered elimination (e.g. Provide bedside commode, provide toileting opportunity at least every 2 hours).
6. Physical restraint may be used to prevent a patient from falling as a last resort, and only after all other methods have proven to be ineffective. Patients will not be physically restrained as a result of experiencing a fall unless all other interventions have been attempted and failed. If physical restraint is necessary to prevent a patient from falling, refer to SPP P-105-DBHSP Use of Restraints.
7. Alterations to the Plan of Care should be considered by the Registered Nurse in the event of changes in the patient's condition, ineffective interventions, and/or undesirable outcomes.
8. In the event a patient experiences a fall, an Unusual Occurrence report will be submitted.
9. In the event a patient experiences a fall, the RN will do one of the following:
   - If the patient is competent to make decisions for oneself, the RN should recommend to the patient that he/she notifies his/her next of kin (primary person listed on face sheet) of the event.
   - If the patient is not competent, or otherwise impaired, the RN should notify the next of kin as soon as appropriate before the end of the shift.

Patient/Family Education

Education will be provided to the patient/family regarding fall risk and interventions to prevent falls. Patients and families, as appropriate, will receive the teaching sheet "Preventing Falls" (#1201032).

Documentation

Documentation of Fall Risk Assessments, interventions and outcomes, and education will be noted on the appropriate Nursing Daily Flow Sheet.

Monitoring

The institution will monitor, through its process improvement activities, the following indicators for patient Falls:

- Patient's designated unit at time of fall.
- Patient Age.
- Patient Gender.
- Fall was/was not observed by staff.
- Fall was/was not assisted.
- Level of patient injury.
- Prior Fall Risk Assessment was/was not completed.
- Patient was/was not identified at risk for fall.
- Fall protocol was/was not followed/physical restraints were/were not in use at time of fall.

REFERENCES

Sentinel Event Alert Issue 14 Fatal Falls: Lessons for the Future. July 12, 2000. Joint Commission on Accreditation of Healthcare Organizations.
2006 JCAHO National Patient Safety Goals.
2007 JCAHO National Patient Safety Goals.
Meade, C., Bursell, A., & Ketelsen, L. Effects of nursing rounds on patients' call light use, satisfaction, and safety. (2006). American Journal of Nursing, 106(9), 58-70.

Rescission: ***PC-13-DBHSP Fall Prevention*** effective 1/08 is hereby rescinded.

APPENDIX B

RESULTS OF ADDITIONAL ANALYSES: ADDRESSING CONCERNS WITH MULTI-COLLINEARITY IN MAIN MULTIPLE LOGISTIC REGRESSION ANALYSES IN SECTION 6.3

Introduction

One of the strengths of the study is its ability to investigate the impact of various fall-related patient characteristics on inpatient falls and to control for them during analyses so that the significant associations between certain physical environmental factors and inpatient falls that can be solely attributable to those environmental factors. As such approach strengthens the study in one hand; it also creates a concern for multi-collinearity or multiple co-dependences among various variables, which might have biased the outcome. Therefore, the current section of the study presents additional analyses that attempted to minimize concerns for multi-collinearity in the statistical models presented in Section 6.3 (Physical Environmental Risk Factors Increasing the Probability of Experiencing a Fall: A Case-Control Study of Inpatient Falls). These additional analyses identified final models with a limited number of highly correlated variables as dropping some of highly correlated variables and that only include variables that considerably contribute to the joint predictive ability of variables in the model.

Procedures

Additional analyses were performed through three phases. First, we adopted Model 3 and its outcome with the sub-group of 78 unassisted falls as a start. So far, Model 3 was identified as a model that showed the most significant joint predictive ability of variables and facilitated identifying a significant environmental predictor (i.e., patient group 3 of Visibility II variable) that the other models could not discern. Second, we ran correlation analyses among all the variables to identify highly correlated variables in Model 3 (See Table B.1). Third, based on the outcome of the analyses, several variations of models were created, depending on which highly correlated variables were dropped from the models. The purpose of these additional analyses was to identify final models that include a limited number of highly correlated variables and that still show a significant joint predictive ability of variables of the model.

Table B.1 Correlation Matrix for Independent and Dependent Variables

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Fall Incidence	1.000	.026	-.083	.111	**.142***	**.206****	.017	.024	-.062	.060	-.060	.094	**.136***	-.050	.015
2. Age	.026	1.000	.125	.114	**.406****	**.342****	**.368****	**.255****	**-.179****	**.302****	-.043	-.069	-.082	-.040	**-.138***
3. Gender	-.083	.125	1.000	-.072	.065	-.035	.085	-.067	-.067	.044	-.070	.092	-.005	.083	.023
4. LOS_Falling	.111	.114	-.072	1.000	.105	**.239****	.072	-.079	-.068	.015	.043	-.056	.000	.056	-.037
5. Mobility	**.142***	**.406****	.065	.105	1.000	**.308****	**.428****	**.250****	-.072	**.309****	-.006	-.057	-.104	-.084	-.040
6. Mentation	.206**	**.342****	-.035	.239**	.308**	1.000	**.374****	**.382****	.082	**.531****	.022	-.062	-.018	-.079	-.065
7. Elimination	.017	**.368****	.085	.072	**.428****	**.374****	1.000	**.355****	.089	**.648****	-.007	-.054	-.028	-.075	-.113
8. Prior Fall HX_C	.024	**.255****	-.067	-.079	**.250****	**.382****	.355**	1.000	.020	**.607****	-.006	.000	.036	-.063	-.038
9. Current_meds	-.062	**-.179****	-.067	-.068	-.072	.082	.089	.020	1.000	**.455****	.085	-.122	.012	-.018	.013
10. Fallriskscore	.060	**.302****	.044	.015	**.309****	**.531****	**.648****	**.607****	**.455****	1.000	.091	-.146*	-.009	-.076	-.099
11. Visibility1_ headarea	-.060	-.043	-.070	.043	-.006	.022	-.007	-.006	.085	.091	1.000	**-.803****	-.112	-.001	.066
12. Visibility3_h210	.094	-.069	.092	-.056	-.057	-.062	-.054	.000	-.122	**-.146***	**-.803****	1.000	**.386****	.046	**.245****
13. Accessibility_ body	**.136***	-.082	-.005	.000	-.104	-.018	-.028	.036	.012	-.009	-.112	**.386****	1.000	.094	**.142***
14. Bathroom_ Location	-.050	-.040	.083	.056	-.084	-.079	-.075	-.063	-.018	-.076	-.001	.046	.094	1.000	**.275****
15. Distance_MED	.015	**-.138***	.023	-.037	-.040	-.065	-.113	-.038	.013	-.099	.066	**.245****	**.142***	**.275****	1.000

* Correlation significant at the .05 level (two-tailed)

** Correlation significant at the .01 level (two-tailed)

Results

Variable Selections Among Fall-related Patient Characteristics

Age and Fall Risk Score Variables versus the Other Five Fall-related Patient Variables

Correlation analyses of variables in Model 3 (Table B.1) revealed significant correlations among the patient-related variables and the environmental variables. Among the patient-related variables, the two variables (i.e., age and fall risk score) are significantly correlated with all other fall-related patient characteristics (i.e., mobility, mentation, elimination, prior fall history, and current fall-related medication). Therefore, it is deemed necessary that either the two variables (i.e. age and fall risk score) or the other five patient variables to be removed from the model. As identifying significant correlations even among the five patient variables (i.e., mobility, mentation, elimination, prior fall history, and current fall-related medication) that would still bring multi-collinearity into question, we decided to exclude the five patient variables from the model. The comparison of statistical outcomes between models before (Model 3) and after (Model 7) excluding the five patient variables is shown in Table B.2. The comparison of the two models indicated that the exclusion of the five patient-related variables did not significantly alter the joint predictive ability of variables between the models.

The overall fit of the model is shown by the -2 x log-likelihood statistic and its associated chi-square statistic, presented in “Omnibus Tests of Model Coefficients” and “Model Summary” of each statistical model (Field, 2005). In addition, the Hosmer and Lemeshow Test also assesses the goodness of fit of a model. Assessing goodness of fit involves investigating how close values predicted by the model are to the observed values (Bewick, Cheek, & Ball, 2005). The outcomes of the tests are also shown in each table. The Hosmer and Lemeshow Test of

Model 7 indicated that the goodness of fit is good. Therefore, in conclusion, the five patient-related variables can be removed from an analysis.

Table B.2 The comparison of Statistical Results between Model 3 and Model 7

Model 3

logit(p) = b + b1*(age) + b2*(gender) + b3*(length of stay at time of falling) + b4*(mobility) + b5*(mentation) + b6*(elimination) + b7*(history of falls) + b8*(current fall-related medication) + b9*(fall risk score) + b10*(**visibility1_headarea**) + b11*(**visibility2_head_seats_210**) + b12*(**accessibility_body**) + b13*(**distance to medication**) + b14*(**bathroom location in related to patient**)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	49.766	27	.005
	Block	49.766	27	.005
	Model	49.766	27	.005

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	226.381[a]	.212	.289

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	7.153	8	.520

Variables in the Equation

		B	Sig.	Exp(B)
Step 1[a]	Age	-.009	.419	.991
	Gender	-.399	.268	.671
	LOS_Falling	.103	.166	1.108
	mobility2	-1.278	.262	.279

Model 7

logit(p) = b + b1*(age) + b2*(gender) + b3*(length of stay at time of falling) + b4*(fall risk score) + b5*(**visibility1_headarea**) + b6*(**visibility2_head_seats_210**) + b7*(**accessibility_body**) + b8*(**distance to medication**) + b9*(**bathroom location in related to patient**)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	24.584	13	.026
	Block	24.584	13	.026
	Model	24.584	13	.026

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	251.563[a]	.111	.151

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	8.252	8	.409

Variables in the Equation

		B	Sig.	Exp(B)
Step 1[a]	Age	.006	.525	1.006
	Gender	-.321	.314	.726

mobility3	.962	.073	2.616
mobility4	.715	.227	2.044
mentation2	-16.318	1.000	.000
mentation3	**1.824**	**.001**	**6.196**
mentation4	1.448	.118	4.254
elimination2	.945	.285	2.573
elimination3	-.343	.499	.710
elimination4	.622	.498	1.862
priorfallhx2	-.648	.202	.523
priorfallhx3	-.727	.123	.483
meds2	2.059	.194	7.839
meds3	-.589	.618	.555
meds4	-.213	.721	.808
meds5	-.669	.207	.512
visibility1_headarea	.011	.082	1.011
vis3_new_h210_2	**1.682**	**.051**	**5.378**
vis3_new_h210_3	**4.477**	**.023**	**87.949**
access_cb_5_new_2	**1.820**	**.057**	**6.169**
access_cb_5_new_3	**1.384**	**.037**	**3.989**
access_cb_5_new_4	**1.665**	**.062**	**5.288**
access_cb_5_new_5	.157	.861	1.171
Bathroom_Location	-.712	.304	.491
Distance_MED	-.002	.206	.998
Constant	-7.203	.109	.001

LOS_Falling	**.144**	**.028**	**1.154**
Fallriskscore	.084	.503	1.087
visibility1_headarea	.012	.052	1.012
vis3_new_h210_2	**1.680**	**.029**	**5.367**
vis3_new_h210_3	**4.368**	**.013**	**78.923**
access_cb_5_new_2	**1.944**	**.024**	**6.986**
access_cb_5_new_3	**1.336**	**.025**	**3.802**
access_cb_5_new_4	**1.590**	**.053**	**4.905**
access_cb_5_new_5	.622	.454	1.863
Bathroom_Location	-.535	.383	.586
Distance_MED	-.002	.135	.998
Constant	-8.596	.039	.000

Age versus Fall Risk Score Variables

Due to the significant correlation between age and fall risk score, it was worthwhile testing how the exclusion of one of the variables would affect the overall fit of the model. The comparison of statistical outcomes between Model 7 (with both age and fall risk score) and either Model 8 (only with age) or Model 9 (only with fall risk score) are presented below in Table B.3 and B.4 respectively.

Statistical results indicated that both models (Models 8 and 9) fitted slightly better than Model 7 but the differences between Model 7 and Models 8 or 9 were insignificant. This indicates that it is acceptable to have both variables (i.e., age and fall risk score) or one of the variables in the model. To minimize the concern of multi-colinearity, we decided to exclude one of the variables. With a slightly better statistical outcome, we decided to further test Model 9.

Table B.3 The comparison of Statistical Results between Models 7 and 8

Model 7

logit(p) = b + b1*(age) + b2*(gender) + b3*(length of stay at time of falling) + b4*(fall risk score) + b5*(**visibility1_headarea**) + b6*(**visibility2_head_seats_210**) + b7*(**accessibility_body**) + b8*(**distance to medication**) + b9*(**bathroom location in related to patient**)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	24.584	13	.026
	Block	24.584	13	.026
	Model	24.584	13	.026

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	251.563[a]	.111	.151

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	8.252	8	.409

Variables in the Equation

		B	Sig.	Exp(B)
Step 1[a]	Age	.006	.525	1.006

Model 8 (Fall Risk Score variable is removed from Model 7)

logit(p) = b + b1*(age) + b2*(gender) + b3*(length of stay at time of falling) + b4*(**visibility1_headarea**) + b5*(**visibility2_head_seats_210**) + b6*(**accessibility_body**) + b7*(**distance to medication**) + b8*(**bathroom location in related to patient**)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	24.133	12	.020
	Block	24.133	12	.020
	Model	24.133	12	.020

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	252.015[a]	.109	.149

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	5.438	8	.710

Variables in the Equation

		B	Sig.	Exp(B)
Step 1[a]	Age	.008	.393	1.008

Gender	-.321	.314	.726
LOS_Falling	**.144**	**.028**	**1.154**
Fallriskscore	.084	.503	1.087
visibility1_headarea	.012	.052	1.012
vis3_new_h210_2	**1.680**	**.029**	**5.367**
vis3_new_h210_3	**4.368**	**.013**	**78.923**
access_cb_5_new_2	**1.944**	**.024**	**6.986**
access_cb_5_new_3	**1.336**	**.025**	**3.802**
access_cb_5_new_4	**1.590**	**.053**	**4.905**
access_cb_5_new_5	.622	.454	1.863
Bathroom_Location	-.535	.383	.586
Distance_MED	-.002	.135	.998
Constant	-8.596	.039	.000

Gender	-.315	.322	.729
LOS_Falling	**.147**	**.024**	**1.158**
visibility1_headarea	.012	.046	1.012
vis3_new_h210_2	**1.672**	**.029**	**5.323**
vis3_new_h210_3	**4.399**	**.013**	**81.383**
access_cb_5_new_2	**1.976**	**.022**	**7.212**
access_cb_5_new_3	**1.354**	**.023**	**3.873**
access_cb_5_new_4	**1.587**	**.053**	**4.887**
access_cb_5_new_5	.645	.436	1.907
Bathroom_Location	-.564	.357	.569
Distance_MED	-.002	.124	.998
Constant	-8.667	.037	.000

Table B.4 The comparison of Statistical Results between Models 7 and 9

Model 7

logit(p) = b + b1*(age) + b2*(gender) + b3*(length of stay at time of falling) + b4*(fall risk score) + b5*(**visibility1_headarea**) + b6*(**visibility2_head_seats_210**) + b7*(**accessibility_body**) + b8*(**distance to medication**) + b9*(**bathroom location in related to patient**)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	24.584	13	.026
	Block	24.584	13	.026
	Model	24.584	13	.026

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	251.563[a]	.111	.151

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	8.252	8	.409

Variables in the Equation

		B	Sig.	Exp(B)
Step 1[a]	Age	.006	.525	1.006

Model 9 (Age variable is removed from Model 7)

logit(p) = b + b1*(gender) + b2*(length of stay at time of falling) + b3*(fall risk score) + b4*(**visibility1_headarea**) + b5*(**visibility2_head_seats_210**) + b6*(**accessibility_body**) + b7*(**distance to medication**) + b8*(**bathroom location in related to patient**)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	24.177	12	.019
	Block	24.177	12	.019
	Model	24.177	12	.019

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	251.970[a]	.109	.149

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	11.332	8	.184

Variables in the Equation

		B	Sig.	Exp(B)
Step 1[a]	Gender	-.301	.342	.740

Gender	-.321	.314	.726
LOS_Falling	**.144**	**.028**	**1.154**
Fallriskscore	.084	.503	1.087
visibility1_headarea	.012	.052	1.012
vis3_new_h210_2	**1.680**	**.029**	**5.367**
vis3_new_h210_3	**4.368**	**.013**	**78.923**
access_cb_5_new_2	**1.944**	**.024**	**6.986**
access_cb_5_new_3	**1.336**	**.025**	**3.802**
access_cb_5_new_4	**1.590**	**.053**	**4.905**
access_cb_5_new_5	.622	.454	1.863
Bathroom_Location	-.535	.383	.586
Distance_MED	-.002	.135	.998
Constant	-8.596	.039	.000

LOS_Falling	.143	.030	1.153
Fallriskscore	.106	.378	1.112
visibility1_headarea	.011	.063	1.011
vis3_new_h210_2	1.595	.035	4.930
vis3_new_h210_3	4.165	.016	64.408
access_cb_5_new_2	1.876	.028	6.526
access_cb_5_new_3	1.283	.029	3.608
access_cb_5_new_4	1.538	.060	4.654
access_cb_5_new_5	.568	.492	1.765
Bathroom_Location	-.520	.395	.594
Distance_MED	-.002	.145	.998
Constant	-7.787	.050	.000

Variable Selections among Environmental Variables

Once we narrowed down variables relevant to fall-related patient characteristics, we scrutinized any correlations among the environmental variables and identified some environmental variables significantly correlated with the other environmental variables: 1) Visibility I variable was significantly correlated with Visibility II variable and 2) Visibility II variable was also correlated with Accessibility and Distance to Medication variables, and 3) Distance to Medication variable was correlated with three environmental variables (i.e., Visibility II, accessibility, and Bathroom Location). In addition, we identified correlations between fall-related patient characteristics and environmental factors: 1) Age variable was correlated with Distance to Medication as Fall Risk Score was with Accessibility.

Based on the findings, several variations of models were also created to identify a model that includes the least number of correlated variables and that presents the effective joint predictive ability of variables.

<u>Visibility I versus Visibility II Variables</u>

Due to the extremely significant correlation between Visibility I and Visibility II ($r = -.803$), we needed to consider excluding one of the variables from Model 9. Therefore, we tested which variable better contributed to the joint predictive ability of variables by constructing two different models: one model with only Visibility I (Model 10) and the other with only Visibility II (Model 11). The comparison of statistical outcomes between Models 9 and 10 and between Models 9 and 11 are shown in Tables B.5 and B.6 respectively. Model 9 was considered as a baseline to identify whether or not the removal of one of the variables (Visibility I and Visibility II) affected the overall joint predictive ability of the model since Model 7 included both variables in the model.

The comparison of statistical results demonstrated that the removal of the variables negatively affected the overall joint predictive ability of the model. Significance levels of Omnibus Tests of Model Coefficients of Models 10 and 11 decreased from .019 (Model 9) to .037 and .052 respectively. This also indicates that the removal of Visibility II significantly affected the overall joint predictive ability of variables in the model as indicated in the reduced outcome in Omnibus Tests of Model Coefficients of Model 11 ($p = .052$). On the other hand, the removal of visibility I did not significantly affected the overall joint predictive ability of variables as indicated in Omnibus Tests of Model Coefficients of Model 10 ($p = .037$).

In conclusion, the statistical results indicated that Visibility II significantly contributed to the overall fit of the model. Therefore, in the interest of minimizing the concern of multi-co-linearity, we decided to exclude Visibility I variable, leaving Visibility II variable in the model.

Table B.5 The comparison of Statistical Results between Models 9 and 10

Model 9

logit(p) = b + b1*(gender) + b2*(length of stay at time of falling) + b3*(fall risk score) + b4*(**visibility1_headarea**) + b5*(**visibility2_head_seats_210**) + b6*(**accessibility_body**) + b7*(**distance to medication**) + b8*(**bathroom location in related to patient**)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	24.177	12	.019
	Block	24.177	12	.019
	Model	24.177	12	.019

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	251.970[a]	.109	.149

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	11.332	8	.184

Variables in the Equation

	B	Sig.	Exp(B)

Model 10 (Visibility II is removed from Model 9)

logit(p) = b + b1*(gender) + b2*(length of stay at time of falling) + b3*(fall risk score) + b4*(**visibility1_headarea**) + b5*(**accessibility_body**) + b6*(**distance to medication**) + b7*(**bathroom location in related to patient**)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	18.172	10	.052
	Block	18.172	10	.052
	Model	18.172	10	.052

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	257.975[a]	.083	.114

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	3.291	8	.915

Variables in the Equation

	B	Sig.	Exp(B)

Step 1[a]	Gender	-.301	.342	.740
	LOS_Falling	.143	.030	1.153
	Fallriskscore	.106	.378	1.112
	visibility1_headarea	.011	.063	1.011
	vis3_new_h210_2	1.595	.035	4.930
	vis3_new_h210_3	4.165	.016	64.408
	access_cb_5_new_2	1.876	.028	6.526
	access_cb_5_new_3	1.283	.029	3.608
	access_cb_5_new_4	1.538	.060	4.654
	access_cb_5_new_5	.568	.492	1.765
	Bathroom_Location	-.520	.395	.594
	Distance_MED	-.002	.145	.998
	Constant	-7.787	.050	.000

Step 1[a]	Gender	-.207	.504	.813
	LOS_Falling	.139	.033	1.149
	Fallriskscore	.100	.398	1.105
	visibility1_headarea	-.003	.212	.997
	access_cb_5_new_2	.460	.441	1.585
	access_cb_5_new_3	.474	.314	1.606
	access_cb_5_new_4	-.006	.990	.994
	access_cb_5_new_5	-.950	.071	.387
	Bathroom_Location	-.233	.664	.792
	Distance_MED	.000	.767	1.000
	Constant	.996	.526	2.707

Table B.6 The comparison of Statistical Results between Models 9 and 11

Model 9

logit(p) = b + b1*(gender) + b2*(length of stay at time of falling) + b3*(fall risk score) + b4*(**visibility1_headarea**) + b5*(**visibility2_head_seats_210**) + b6*(**accessibility_body**) + b7*(**distance to medication**) + b8*(**bathroom location in related to patient**)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	24.177	12	.019
	Block	24.177	12	.019
	Model	24.177	12	.019

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	251.970[a]	.109	.149

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	11.332	8	.184

Model 11 (Visibility I is removed from Model 9)

logit(p) = b + b1*(gender) + b2*(length of stay at time of falling) + b3*(fall risk score) +b4*(**visibility2_head_seats_210**) + b5*(**accessibility_body**) + b6*(**distance to medication**) + b7*(**bathroom location in related to patient**)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	20.685	11	.037
	Block	20.685	11	.037
	Model	20.685	11	.037

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	255.462[a]	.094	.129

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	11.031	8	.200

Variables in the Equation

		B	Sig.	Exp(B)
Step 1[a]	Gender	-.301	.342	.740
	LOS_Falling	.143	.030	1.153
	Fallriskscore	.106	.378	1.112
	visibility1_headarea	.011	.063	1.011
	vis3_new_h210_2	1.595	.035	4.930
	vis3_new_h210_3	4.165	.016	64.408
	access_cb_5_new_2	1.876	.028	6.526
	access_cb_5_new_3	1.283	.029	3.608
	access_cb_5_new_4	1.538	.060	4.654
	access_cb_5_new_5	.568	.492	1.765
	Bathroom_Location	-.520	.395	.594
	Distance_MED	-.002	.145	.998
	Constant	-7.787	.050	.000

Variables in the Equation

		B	Sig.	Exp(B)
Step 1[a]	Gender	-.251	.423	.778
	LOS_Falling	.140	.033	1.150
	Fallriskscore	.111	.351	1.118
	vis3_new_h210_2	.443	**.287**	**1.558**
	vis3_new_h210_3	1.178	**.047**	**3.247**
	access_cb_5_new_2	.969	.157	2.636
	access_cb_5_new_3	.762	.135	2.142
	access_cb_5_new_4	.463	.421	1.589
	access_cb_5_new_5	-.503	.401	.605
	Bathroom_Location	-.323	.582	.724
	Distance_MED	-.001	.488	.999
	Constant	-.753	.524	.471

Distance to Medication versus the Three Other Environmental Variables

Since Distance to Medication variable was correlated with three other environmental variables (i.e., Visibility II, Accessibility, and Bathroom Location), we also needed to consider the exclusion of the variable to avoid possible co-dependence among the variables. When Distance to Medication variable was excluded from Model 10, statistical results of Model 12 indicated that the overall fit of the model was slightly improved, as shown in Table B.7. Therefore, the variable (Distance to Medication) was excluded from the model.

Bathroom Location

So far, we excluded several variables that were a concern of multi-collinearity from the original statistical model and resulted in Model 12, which includes three fall-related patient characteristics (i.e., Gender, LOS at Time of Falling, and Fall Risk Score) and three environmental variables (i.e., Visibility II, Accessibility, and Bathroom Location) (See Table B.7). In Model 12, it seemed that Bathroom Location variable was not a concern of multi-collinearity because the model no longer included any of the variables highly correlated with the variable (Bathroom Location). However, it was still worthwhile testing where or not the exclusion of the variable affected the overall fit of the model because the variable was consistently associated with insignificant outcomes throughout statistical analyses. It was doubtful that the variable was actually contributing to the overall fit of the model. The statistical results of Models 13 indicated that the overall fit of the model was slightly improved when we excluded Bathroom Location variable from Model 12. Therefore, it could be a reasonable option that we exclude the variable from the model. However, we can still include the variable in the model to emphasize the fact that we takes into account the impact of the variable and, although not significant in the current study, that it can be something that needs further investigation in future studies. After all, experts in the field suggest that the variable (Bathroom Location) is associated with inpatient falls. Along the similar lines of argument, we can also consider to include Distance to Medication variable in the final model because no logical explanations can be provided so far why Accessibility and Distance to Medication variables are correlated as seen in the current study. It is possible that those are not correlated in other studies and, therefore, each variable needs separate attention. It is still convincing to the investigator of the current study that Distance to Medication matters because it affects staff's movement on unit as a functional focal point as the layout of the unit determines accessibility from one space to another within the unit, which in turn affects staff's movement on unit.

Table B.7 The comparison of Statistical Results between Models 10 and 12

Model 10

logit(p) = b + b1*(gender) + b2*(length of stay at time of falling) + b3*(fall risk score) +b4*(**visibility2_head_seats_210**) + b5*(**accessibility_body**) + b6*(**distance to medication**) + b7*(**bathroom location in related to patient**)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	20.685	11	.037
	Block	20.685	11	.037
	Model	20.685	11	.037

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	255.462[a]	.094	.129

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	11.031	8	.200

Variables in the Equation

		B	Sig.	Exp(B)
Step 1[a]	Gender	-.251	.423	.778
	LOS_Falling	**.140**	**.033**	**1.150**

Model 12 (Distance to Medication is excluded from Model 10)

logit(p) = b + b1*(gender) + b2*(length of stay at time of falling) + b3*(fall risk score) +b4*(**visibility2_head_seats_210**) + b5*(**accessibility_body**) + b6*(**bathroom location in related to patient**)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	20.186	10	.028
	Block	20.186	10	.028
	Model	20.186	10	.028

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	255.961[a]	.092	.126

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	6.218	8	.623

Variables in the Equation

		B	Sig.	Exp(B)
Step 1[a]	Gender	-.266	.395	.767
	LOS_Falling	**.145**	**.026**	**1.156**

Fallriskscore	.111	.351	1.118
vis3_new_h210_2	.443	.287	1.558
vis3_new_h210_3	**1.178**	**.047**	**3.247**
access_cb_5_new_2	.969	.157	2.636
access_cb_5_new_3	.762	.135	2.142
access_cb_5_new_4	.463	.421	1.589
access_cb_5_new_5	-.503	.401	.605
Bathroom_Location	-.323	.582	.724
Distance_MED	-.001	.488	.999
Constant	-.753	.524	.471

Fallriskscore	.115	.333	1.122
vis3_new_h210_2	.377	.345	1.458
vis3_new_h210_3	**1.072**	**.060**	**2.922**
access_cb_5_new_2	.839	.203	2.315
access_cb_5_new_3	.607	.185	1.835
access_cb_5_new_4	.559	.317	1.750
access_cb_5_new_5	-.493	.409	.611
Bathroom_Location	-.403	.479	.668
Constant	-1.117	.292	.327

Table B.8 The comparison of Statistical Results between Models 12 and 13

Model 12

logit(p) = b + b1*(gender) + b2*(length of stay at time of falling) + b3*(fall risk score) +b4*(**visibility2_head_seats_210**) + b5*(**accessibility_body**) + b6*(**bathroom location in related to patient**)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	20.186	10	.028
	Block	20.186	10	.028
	Model	20.186	10	.028

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	255.961[a]	.092	.126

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	6.218	8	.623

Variables in the Equation

		B	Sig.	Exp(B)
Step 1[a]	Gender	-.266	.395	.767
	LOS_Falling	.145	.026	1.156
	Fallriskscore	.115	.333	1.122

Model 13 (Bathroom Location is excluded from Model 12)

logit(p) = b + b1*(gender) + b2*(length of stay at time of falling) + b3*(fall risk score) +b4*(**visibility2_head_seats_210**) + b5*(**accessibility_body**)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	19.676	9	.020
	Block	19.676	9	.020
	Model	19.676	9	.020

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	256.472[a]	.090	.123

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	4.972	8	.761

Variables in the Equation

		B	Sig.	Exp(B)
Step 1[a]	Gender	-.268	.391	.765
	LOS_Falling	.146	.025	1.158
	Fallriskscore	.121	.305	1.129

vis3_new_h210_2	.377	.345	1.458
vis3_new_h210_3	**1.072**	**.060**	**2.922**
access_cb_5_new_2	.839	.203	2.315
access_cb_5_new_3	.607	.185	1.835
access_cb_5_new_4	.559	.317	1.750
access_cb_5_new_5	-.493	.409	.611
Bathroom_Location	-.403	.479	.668
Constant	-1.117	.292	.327

vis3_new_h210_2	.445	.250	1.561
vis3_new_h210_3	1.024	.070	2.784
access_cb_5_new_2	.776	.233	2.173
access_cb_5_new_3	.631	.168	1.880
access_cb_5_new_4	.596	.285	1.814
access_cb_5_new_5	-.515	.387	.597
Constant	-1.606	.049	.201

Visibility I and Accessibility

Excluding several variables as a solution to multi-collinearity in the original model, Model 12 included the three fall-related patient characteristics (i.e., Gender, LOS at Time of Falling, and Fall Risk Score) and the three environmental variables (i.e., Visibility II, Accessibility, and Bathroom Location). In Model 12, we still had correlated variables (i.e., Visibility II and Accessibility). Therefore, two additional models (Models 14 and 15) were constructed to understand how the removal of each variable affected the overall fit of the model. Statistical results of Models 13 and 14 indicated that the removal of Visibility II and Accessibility, respectively, reduced the overall fit of the model from p = .028 (Model 12) to p = .035 (Model 13 - after the removal of Visibility II) or from p = .028 (Model 12) to p = .058 (Model 14 - after the removal of Accessibility). As shown, the magnitude of the effect was more significant when we removed Accessibility variable from the model than Visibility II. However, it was important to note that one of individual Visibility II measures still remained significant even after excluding Accessibility variable, which was correlated with the variable (Visibility II). So, we can confirm that the significant outcome to the patient group 3 of Visibility II variable is not due to any association of Visibility II with Accessibility variable. The variable itself has enough explanatory power to be significant. On the other hand, for accessibility variable, statistical outcomes before and after the removal of Visibility II variable were inconsistent: one insignificant sub-variable turned out to be significant after removing the variable of Visibility II from the model. With the inconsistent outcomes, we could suspect the co-dependence or the relationship between Visibility II and Accessibility variables might have been playing its role in statistical outcomes and, therefore, may have affected the outcome of each variable.

Even with such observation, we concluded to include both Visibility II and Accessibility variables in the final model because of following reasons: 1) One of sub-measures of Visibility II was a significant predictor that was consistently significant throughout the analyses and 2) Accessibility measure was significantly contributing the overall fit of the model, as shown in Model 14. In addition, the investigators of the current study proposed that Visibility II and Accessibility variables are different measures that should be taken into account simultaneously even though they show some level of correlations. Therefore, both variables were included in the final model for further investigation.

Table B.9 The comparison of Statistical Results between Models 12 and 14

Model 12

logit(p) = b + b1*(gender) + b2*(length of stay at time of falling) + b3*(fall risk score) +b4*(**visibility2_head_seats_210**) + b5*(**accessibility_body**) + b6*(**bathroom location in related to patient**)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	20.186	10	.028
	Block	20.186	10	.028
	Model	20.186	10	.028

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	255.961[a]	.092	.126

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	6.218	8	.623

Variables in the Equation

		B	Sig.	Exp(B)
Step 1[a]	Gender	-.266	.395	.767
	LOS_Falling	.145	.026	1.156
	Fallriskscore	.115	.333	1.122

Model 14 (Accessibility is excluded from Model 12)

logit(p) = b + b1*(gender) + b2*(length of stay at time of falling) + b3*(fall risk score) +b4*(**visibility2_head_seats_210**) + b6*(**bathroom location in related to patient**)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	12.190	6	.058
	Block	12.190	6	.058
	Model	12.190	6	.058

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	263.957[a]	.057	.077

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	4.421	8	.817

Variables in the Equation

		B	Sig.	Exp(B)
Step 1[a]	Gender	-.359	.234	.698
	LOS_Falling	.140	.029	1.150
	Fallriskscore	.109	.347	1.115

vis3_new_h210_2	.377	.345	1.458
vis3_new_h210_3	**1.072**	**.060**	**2.922**
access_cb_5_new_2	.839	.203	2.315
access_cb_5_new_3	.607	.185	1.835
access_cb_5_new_4	.559	.317	1.750
access_cb_5_new_5	-.493	.409	.611
Bathroom_Location	-.403	.479	.668
Constant	-1.117	.292	.327

vis3_new_h210_2	.126	.733	1.135
vis3_new_h210_3	.852	.057	2.345
Bathroom_Location	-.527	.324	.590
Constant	-.313	.725	.731

Table B.10 The comparison of Statistical Results between Models 12 and 15

Model 12

logit(p) = b + b1*(gender) + b2*(length of stay at time of falling) + b3*(fall risk score) +b4*(**visibility2_head_seats_210**) + b5*(**accessibility_body**) + b6*(**bathroom location in related to patient**)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	20.186	10	.028
	Block	20.186	10	.028
	Model	20.186	10	.028

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	255.961[a]	.092	.126

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	6.218	8	.623

Variables in the Equation

		B	Sig.	Exp(B)
Step 1[a]	Gender	-.266	.395	.767
	LOS_Falling	.145	.026	1.156
	Fallriskscore	.115	.333	1.122

Model 15 (Visibility II is excluded from Model 12)

logit(p) = b + b1*(gender) + b2*(length of stay at time of falling) + b3*(fall risk score) +b4*(**accessibility_body**) + b6*(**bathroom location in related to patient**)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	16.541	8	.035
	Block	16.541	8	.035
	Model	16.541	8	.035

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	259.606[a]	.076	.104

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	5.138	8	.743

Variables in the Equation

		B	Sig.	Exp(B)
Step 1[a]	Gender	-.181	.554	.834
	LOS_Falling	.142	.029	1.153
	Fallriskscore	.083	.474	1.086

vis3_new_h210_2	.377	.345	1.458
vis3_new_h210_3	**1.072**	**.060**	**2.922**
access_cb_5_new_2	.839	.203	2.315
access_cb_5_new_3	.607	.185	1.835
access_cb_5_new_4	.559	.317	1.750
access_cb_5_new_5	-.493	.409	.611
Bathroom_Location	-.403	.479	.668
Constant	-1.117	.292	.327

access_cb_5_new_2	.235	.676	1.265
access_cb_5_new_3	.320	.450	1.377
access_cb_5_new_4	-.015	.974	.985
access_cb_5_new_5	-.977	.058	.377
Bathroom_Location	-.258	.617	.772
Constant	-.551	.537	.576

Conclusions

As a result of the additional investigation (or analyses), we narrowed down our options of statistical models into two (Models 10 and 13), which included the limited number of correlated variables and that still showed good joint predictive abilities of variables in the model. The investigation identified most significant variables contributing the overall fit of the final model as follows: 1) Gender, LOS at Time of Falling, and Fall Risk Score for fall-related patient variables and 2) Visibility II and Accessibility for environmental variables. Although the statistical outcomes of models mainly led decisions around whether or not we excluded variables, it might be preferable to keep some variables such as Bathroom Location or Distance to Medication in the final model mainly to emphasize the need for further investigation of those variables in future studies, even though they did not contribute the overall fit of the model.

It is important to note that, in both models, the outcome of one sub-measure (i.e., patient group 3) of Visibility II was consistently significant as opposed to the outcome of several sub-measures of Accessibility. Therefore, we can conclude that the relationship between the variable (the sub-measure of Visibility II) and the outcome can be solely attributable to it. The significant outcome of several sub-measures of Accessibility disappeared as we excluded variables correlated with it. Therefore, we may suspect co-dependence among those variables and its impact on the outcome and conclude that the outcome relevant to Accessibility measure is inconclusive.

Table B.11 Two Options of Final Models

Model 10

logit(p) = b + b1*(gender) + b2*(length of stay at time of falling) + b3*(fall risk score) +b4*(**visibility2_head_seats_210**) + b5*(**accessibility_body**) + b6*(**distance to medication**) + b7*(**bathroom location in related to patient**)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	20.685	11	.037
	Block	20.685	11	.037
	Model	20.685	11	.037

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	255.462[a]	.094	.129

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	11.031	8	.200

Variables in the Equation

		B	Sig.	Exp(B)
Step 1[a]	Gender	-.251	.423	.778

Model 13 (Both Distance to Medication and Bathroom Location are excluded from Model 10)

logit(p) = b + b1*(gender) + b2*(length of stay at time of falling) + b3*(fall risk score) +b4*(**visibility2_head_seats_210**) + b5*(**accessibility_body**)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	19.676	9	.020
	Block	19.676	9	.020
	Model	19.676	9	.020

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	256.472[a]	.090	.123

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	4.972	8	.761

Variables in the Equation

		B	Sig.	Exp(B)
Step 1[a]	Gender	-.268	.391	.765

LOS_Falling	**.140**	**.033**	**1.150**
Fallriskscore	.111	.351	1.118
vis3_new_h210_2	.443	.287	1.558
vis3_new_h210_3	**1.178**	**.047**	**3.247**
access_cb_5_new_2	.969	.157	2.636
access_cb_5_new_3	.762	.135	2.142
access_cb_5_new_4	.463	.421	1.589
access_cb_5_new_5	-.503	.401	.605
Bathroom_Location	-.323	.582	.724
Distance_MED	-.001	.488	.999
Constant	-.753	.524	.471

LOS_Falling	.146	.025	1.158
Fallriskscore	.121	.305	1.129
vis3_new_h210_2	.445	.250	1.561
vis3_new_h210_3	1.024	.070	2.784
access_cb_5_new_2	.776	.233	2.173
access_cb_5_new_3	.631	.168	1.880
access_cb_5_new_4	.596	.285	1.814
access_cb_5_new_5	-.515	.387	.597
Constant	-1.606	.049	.201

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